CARDIAC EMERGENCIES AND HEART FAILURE

Prevention and Treatment

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NORMAL BLOOD PRESSURE AND HYPERTENSION

New Definitions

BY

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DEDICATION

This book is dedicated to Mrs Hilda Master to Arthur Jr to Edith and to Camilla Master who have been a source of great help and of deep inspiration to the authors

Arthur M Master
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Max B Walters

PREFACE

EVERY physician be he general practitioner or specialist uses a sphygmomanometer The blood pressure reading thereby obtained may frequently serve as an aid in diagnosis and prognosis if the clearly defined *normal variations* in the limits of the blood pressure are taken into consideration in each case Hitherto the almost universally accepted limits of normal blood pressure and of hypertension have been constants They were fixed unvarying criteria by which the normality or abnormality of the blood pressure was determined They were applied to adults of all ages of both sexes and of different weights

In tracing the evolution of the concept of normal blood pressure in clinical medicine it is surprising to find that the definition of its normality depended largely on the results of statistical studies by life insurance companies The conclusions drawn from such investigations however are obviously not applicable to clinical medicine since they are based on findings in a selective group of individuals and are derived from a statistical analysis of group mortality rather than from an examination of large numbers of unselected normal people

In clinical medicine it is advisable to make a diagnosis of a disease or pathological condition only when at least several signs or symptoms are present Such a sound approach has been bypassed in cases of hypertension Most physicians arbitrarily classify a person as hypertensive if he has a systolic blood pressure of 150 mm mercury and a diastolic blood pressure above 90 or 95 mm mercury in the absence of any other findings This attitude is unsound Because unvarying blood pressure limits have been applied to all age groups and to both men and women numerous mistaken diagnoses of hypertension have been made in the past Patients who were in reality normal have been made emotional and physical invalids They were advised to lessen their activities and to engage only in non strenuous occupations The psychic trauma thereby imposed upon these normal hypertensives the resultant disruption of the social life of the patients and their families the economic loss to the individual to industry and to the state have been great

The present work was undertaken in an attempt to establish the *true normal limits* of the blood pressure A statistical study was made of 74 000 unselected individuals representative of the average healthy working population These new limits have been found to be definitely higher than those heretofore used and to vary with the age the sex and the weight of the subject

The new limits of normal blood pressure herein proposed should be applied in each case not as an isolated criterion of disease but in correlation with the entire clinical picture The same blood pressure may be an indication of disease in one patient and of little or no clinical significance in another Used sensibly these new limits will prevent the frequent erroneous diagnosis of hypertension We have applied them in clinical practice for more than three years and are convinced that they are well founded

The evolution of the concept of blood pressure is of great medical and historical interest The circulation poorly understood as it was impressed men even in ancient times The old Egyptians compared the force of the pulse beat to the ebb and flow of the Nile which they considered to be one of the majestic phenomena of their time

The history of blood pressure and of hypertension is interwoven The concept of increased blood pressure was clear in the mind of some clinicians even before the era of clinical sphygmomanometry The sphygmomanometer the instrument with which every medical student is familiar after his first day on a hospital ward is in itself the evolutionary product of long lasting research by famous physicists and physiologists

It is our hope that this book will prove to be of help to physicians in their practice and to investigators engaged in various experimental and clinical studies

It is a pleasure to acknowledge our debt of gratitude to Dr Samuel Kahn of New York His generous help in editing has made the preparation of this book a pleasure Mrs Henry Tamblyn of Walpole Mass labored efficiently at tedious details Dr Harry I Jaffe of New York gave us valuable criticisms Mr Herbert H Marks and Dr Louis I Dublin of the Metropolitan Life Insurance Company were co authors in the original investigations on which this book is fundamentally based

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Chapter I

HISTORY OF PRINCIPLES AND METHODS OF CLINICAL SPHYGMOMANOMETRY

To a medical student entering the medical wards of a hospital for the first time the present day measurement of blood pressure appears to be a simple routine procedure Yet the evolution of this important common clinical test required more than a century of research and experimentation by many famous physiologists and physicians—Hales Marey von Basch Potain and others Their brilliant ideas and skillful devices pointed the way to the ultimate solution of the problem of accurate clinical blood pressure measurement During the course of their experimentation many modifications were introduced by numerous other investigators resulting in the production of a large number of devices to measure the blood pressure The great majority of these were cumbersome and impractical and did not withstand the test of time and experience only occasionally did they improve upon the original ideas and methods of procedure The noteworthy developments of this long series of experimental studies finally culminated in the simple technique now in use We shall attempt in this presentation to discuss the more important milestones in this evolution

The first actual measurement of the blood pressure was performed by Stephen Hales[1] (Figure 1) in 1733 about a hundred years after Harvey had elucidated the mechanics of the circulation Hales used the direct approach and his method can best be described in his own words In December I caused a mare to be tied down alive on her back she was 14 hands high and about fourteen years of age had a fistula on her withers was neither very lean nor yet lusty having laid open the left crural artery about 3 inches from her belly I inserted into it a brass pipe whose bore was $\frac{1}{6}$ of an inch in diameter and to that by means of another brass pipe which was fitly adapted to it I fixed a glass tube of nearly the same diameter which was 9 feet in length then untying the ligature on the artery the blood rose in the tube 8 feet in length 3 inches perpendicular above the level of the left ventricle of the heart We may admire the skillfulness and accuracy of his technique crude as it was by taking special care to place the tube at the heart level he obtained an accurate blood pressure measurement Similar measurements were carried out by Hales on sheep dogs and other animals the results he obtained are still considered to be correct Obviously Hales method is crude and

impractical and is only of historical interest but it represents the first measurement of blood pressure ever performed

It was not until another century had passed following Hales classical experiment before the first technical improvement for measuring the blood pressure was made In 1828 Poiseuille [3] introduced the U form of mercury manometer for blood pressure measurement -the hemo dynamometre (Figure 2A) This consisted of a U shaped tube 7 mm in diameter The shorter arm was introduced into the artery of an animal



Fig 1 —Stephen Hales (1677 1761)
First to measure the blood pressure (in animals) with the direct intra arterial method

after having been filled with a solution of subcarbonate of soda to prevent clotting The intraarterial pressure was transmitted directly to the mercury column and could be read on the manometer Continuous approximate determinations of the blood pressure could thus be made in animals The disadvantage of this method was that the large diameter of the tube and the heavy weight of the mercury column prevented the registration of smaller oscillations and pressure variations

Magendie[45] in 1850 improved the Poiseuille manometer by introducing a large reservoir partly filled with mercury (Figure 2B) From its lower end arose a thin 2 mm tube The reservoir was connected to the artery of the animal so that the pressure variations acted over a comparatively large surface of mercury These variations could be measured by changes in the height of the mercury column in the attached tube By increasing the surface over which the pressure variations could

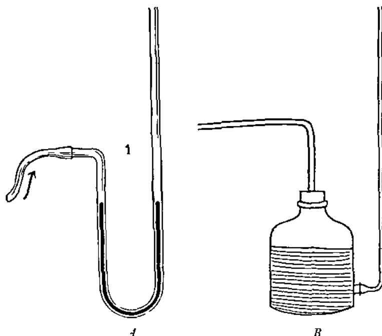


FIG 2A —POISEUILLE HEMODYNAMOMETRE (1828)

U tube filled with mercury Short arm connected to artery of animal and filled with solution of subcarbonate of soda to prevent clotting

FIG 2B —MAGENDIE MANOMETER (1850)

Increased the sensitivity of the Poiseuille Manometer by introducing a mercury reservoir and decreasing the diameter of the glass

act and by decreasing the diameter of the manometer and hence the weight of the mercury column in it this system was much more sensitive to small changes in pressure Its principle was incorporated in later instruments which employed a mercury manometer to measure the blood pressure

In 1847 Carl Ludwig[6] of the University of Leipzig introduced a method for the direct registration of the intraarterial blood pressure and its variations He placed an ivory float in the taller arm of the Poiseuille

manometer to this he attached a rigid writing arm (Figure 3) The movements of the mercury column were thus transmitted to the writing arm and were recorded on the revolving drum of a kymograph Although the kymograph had actually been developed by other physicists (Poncelet Morin)[4,5] it was first introduced into medical physiology by Ludwig It still is a fundamental device in the physiology laboratory employed to register various mechanical phenomena Ludwig was the first to use it to record the blood pressure

Although the determination of the direct intraarterial blood pressure by these procedures was possible in animals it was not feasible in man Many physicians in the past had been impressed with the importance

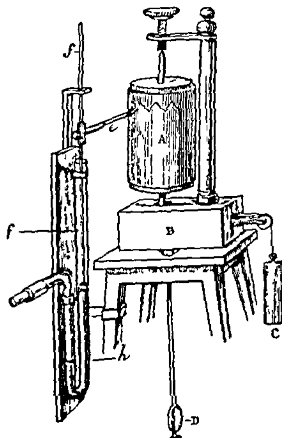


FIG 3 —LUDWIG KYMOGRAPH (1847)

A—smoked paper B stand (base) C—weight D—pendulum of clockwork F—writing point f—float h—Mercury manometer

The ivory float is placed in the taller arm of the Poiseuille manometer and is connected to the writing arm The blood pressure changes are recorded continuously on a revolving kymograph

of the force of the pulse but Julius Herrison [7, 8] of Paris was the first to devise a method for the objective demonstration of the force of arterial pulsation in man With him began the indirect measurement of blood pressure in human beings In 1834 he introduced his Sphygmometre (Figure 4) This consisted of half a metal sphere connected to a graduated capillary tube with a membrane covering its plane surface The system was filled with mercury so that the column of mercury extended part way up to the capillary tube When the membrane was

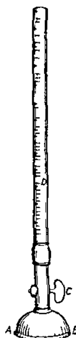


FIG 4 —HERRISON SPHYGMOMETRE (1834)

AB—half a metal sphere covered with membrane C—stopcock D—capillary tube filled with mercury

The membrane is placed on the radial artery and the magnitude of oscillation of the mercury column is noted

placed on the radial artery Herrison saw the oscillations of the mercury column which corresponded to the arterial pulsations and actually measured the magnitude of these pulsations He stated that with this instrument it would be possible for the physican to record the exact magnitude of the pulse in each patient hence for the first time an objective method was available to follow changes in radial artery pulsations during the course of an illness or during health Although Herrison s original purpose was only to demonstrate the degree of oscillation

of the radial pulse his instrument indirectly demonstrated and measured the blood pressure in man

In 1855 Karl Vierordt [9] a German physiologist introduced the principle of measuring the amount of counter pressure necessary to obliterate the pulsations in a peripheral artery as an index of the blood pressure level He devised an ingenious but cumbersome and impractical sphygmograph for the purpose of utilizing and demonstrating this new approach to blood pressure measurement A partially weighted button connected by means of a metal rod to a writing lever (Figure 5), was placed on the radial pulse The oscillations were recorded on a kymograph Increasing weights were placed in receptacles on the metal rod The amount of weight required to obliterate the radial pulsation was taken as an index of systolic pressure

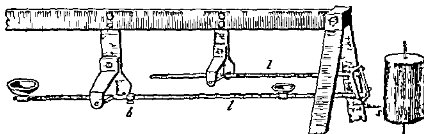


FIG 5 —VIERORDT SPHYGMOGRAPH (1855)
b—metal button *l*—metal bar with plates to hold weights *s*—writing point
Metal button applied to radial artery amount of weight required to obliterate radial artery pulsations taken as index of systolic pressure

Marey [10–1] the well known French physiologist was able to improve the rough and cumbersome sphygmograph of Vierordt In 1860 he devised a small accurate instrument which was applied to the forearm and gave excellent radial pulse records (Figure 6B) Later he improved the sensitivity and accuracy of his sphygmograph by using a rubber tambour to transmit the arterial pulsations to the writing arm (Figure 6C) Following the introduction of Marey s practical sphygmograph numerous physiologists employed it to determine the peripheral blood pressure by utilizing Vierordt s principle—*i e* measuring the weight required to obliterate the radial pulsations Foster[13] (1867) Behier[14] (1868) Landois[15] (1872) Philadelphien[16] (1896) —all used this principle in the instruments they constructed An example of this type of apparatus is the one devised by Philadelphien (Figure 7) which enjoyed a wide use for a short period of time It was soon discarded when more accurate devices employing different principles became available The measurement of the blood pressure with this type of apparatus was grossly

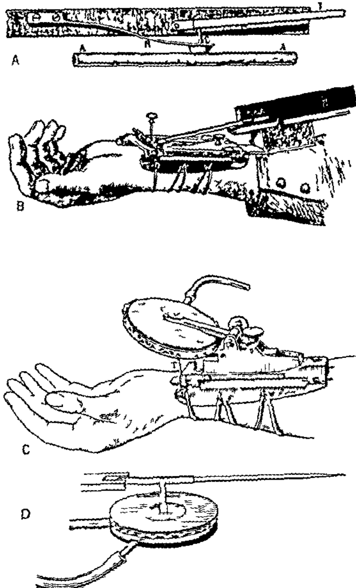


Fig 6 —Marey Sphygmograph

A—Principle of method used —*Compact sphygmographs easily attached to forearm*

AA—segment of artery L—writing arm C—small rounded button which transmits arterial movement to the writing arm

B —First model Direct transmission sphygmograph Introduced 1860 The expansions of the artery are transmitted to a lever recording the movements on the smoked paper

C – Improved model Indirect (pneumatic) transmission sphygmograph The movements of the pulse are transmitted to a rubber tambour and the changes in pressures in this tambour are recorded on the smoked paper

D —Tambour with writing arm

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inaccurate, the results obtained being between two and ten times the normal.

Using Vierordt's method of radial pulse obliteration by means of a solid medium, several other machines were later produced. Waldenburg[17] in 1875 introduced a rather complicated instrument ("Pulsuhr" or "pulse watch") (Figure 8) which is of historic interest in that he used the blood pressure readings thereby obtained to publish the first book on blood pressure in man. In *1888* Bloch[18] devised a simple instrument which was small enough to easily fit into a physician's vest pocket (Figure 9). Pressure was gradually exerted by the metal button on a fingernail placed directly on the radial artery. At the instant the radial

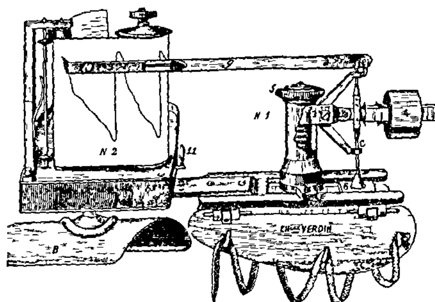


FIG. 7.—PHILADELPHIEN SPHYGMOMETROGRAPHE (1896)

No. 1.—the large leather armlet at the lower right of the figure is fastened around the forearm. No. 2—revolving paper roll connected with watch system—No. 7—resting on the forearm.—No. 8. No. 3—graduated aluminum bar connected with the ivory button—No. 6—which obliterates the radial artery. No. 4—weight moving without friction on graduated metal bar by means of which the pressure on the artery is increased until the oscillations recorded on the paper disappear. No. 5—screw top regulating the position of the ivory button on the radial artery, simultaneously putting the long arm—No. 9—with writing point—No. 10—parallel to the aluminum bar, permitting the inscription of the pulsations of the radial artery on the moving paper. No. 11.—handle to start and stop sphygmometrograph. C—lever attached to ivory button—No. 6—which compresses the radial artery.

The pressure on the graduated aluminum bar necessary to obliterate the radial artery corresponds to the true blood pressure.

pulsations disappeared the systolic pressure was read on the gauge All these devices were grossly inaccurate rather difficult to apply in clinical medicine and hence were employed for only short periods of time

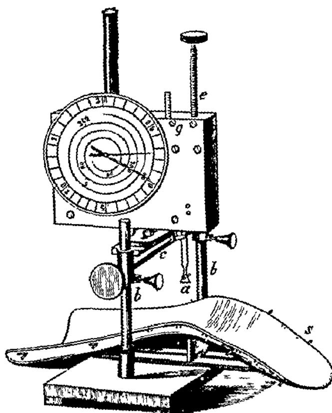


FIG 8—WALDENBURG PULSUHR (1875)
s—arm rest a—metal button e—screw b—vertical adjustment c—horizontal adjustment g—box with spring mechanism and scale
Metal button placed on radial artery amount of force required to obliterate pulsation taken as an indication of systolic pressure

In 1875 Marey[19] introduced an apparatus for the more accurate measurement of the blood pressure Instead of applying local pressure to the arterial wall only this instrument compressed the blood vessels of the forearm from all sides equally (Figure 10) The forearm and hand were inserted through a tight fitting rubber collar into a metal box which was filled with water A glass window in the box gave a view of its interior The box was connected with a mercury manometer and a recording tambour By means of an attached reservoir the pressure in

the box could be gradually raised As the pressure in the box was raised, the pulse waves were transmitted to the fluid and thence to the tambour The pulsations increased in amplitude up to a certain point and then diminished Long before the pulsations disappeared entirely the skin of the arm was seen to blanch thus showing that the vessels had been collapsed and their intraarterial pressure overcome

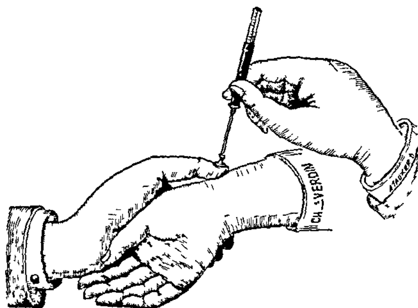


Fig 9.—Bloch Sphygmometer (1888)
Pressure exerted by a metal button on a fingernail placed on radial artery until the pulse is obliterated At that instant the pressure is read on the gauge

Marey believed that the point at which the maximum oscillations occurred and the time when the skin was seen to blanch were the two important indexes of blood pressure measurement He thought that at the point when the maximum oscillations developed the external pressure of the water in the box exactly balanced the internal pressure of the blood within the artery so that the arterial wall was merely a floating membrane Hence at this instant the pressure of the blood within the artery could be considered as being transmitted directly to the mercury manometer and the recording tambour This Marey felt represented the true level of the intravascular pressure

Later many investigators including Janeway [2] believed that the point of maximum pulsation represented the level of the diastolic pressure Subsequently [9] Marey was credited with having held the opinion which Janeway had expressed It is evident however from reading his original

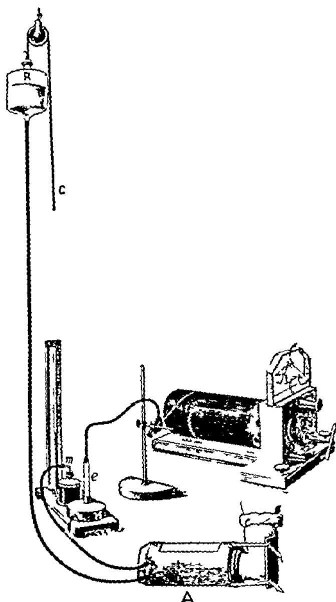


FIG 10 —MAREY SPHYGMOMANOMETER (1878)

A—forearm in box filled with water and having small glass window R—reservoir C—pulley system m—mercury manometer M—rubber tambour

Pressure is gradually raised in the metal box to the point of maximum oscillation and to the point of skin blanching Both criteria are used as indexes of blood pressure measurement

description that Marey considered the external pressure at which the maximum pulsation of the arterial walls occurs as a new indirect measure of the blood pressure giving no thought to its relationship to systolic or diastolic pressure Von Recklinghausen and other investigators subsequently showed that external pressure which produced the maximum oscillations was actually closer to the mean blood pressure *[21] than to the diastolic pressure

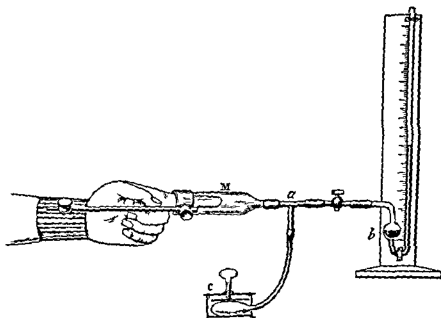


FIG 11 —MAREY FINGER SPHYGMOMANOMETER (1878)

M —glass receptacle b—mercury manometer a—T tube c—bulb to increase pressure in water filled system

Oscillations of digital arteries are transmitted directly to the mercury column

* *The mean pressure is usually given as half the sum of the values for the systolic and diastolic pressures This is not strictly accurate and a true numerical expression in millimeters of mercury of the mean pressure is not simply the average of the values of systolic and diastolic pressures i e the sum of these values divided by 2 (arithmetic mean) The average pressure throughout the cardiac cycle i e the true or geometric mean is somewhat lower than this lying nearer the diastolic than the systolic pressure If the pressure fell in a steady slope from its systolic to its diastolic level throughout the cardiac cycle and the pulse wave inscribed a perfect triangle then the arithmetic and geometric means would be identical The descending limb of the pulse curve however presents one or more secondary waves which prevent it from assuming the purely triangular form*

Three years later (1878) Marey [2, 23] devised a second smaller apparatus into which only one finger was inserted (Figure 11) The pulsations were transmitted directly to the mercury column According to Marey s description One finds at which pressure the maximum oscillations occur and at this moment one reads on the scale of the manometer the absolute value of the maximum and the minimum Using this finger apparatus Marey discusses the possibility for the first time of measuring the constant level or minimum level of the blood pressure So Marey may be considered the first to make a successful attempt at indirectly measuring the diastolic pressure in man



Fig 12 —Mosso Sphygmomanometer (1895)
Same principle as used by Marey but volume changes are measured simultaneously in 4 fingers

This instrument was unsatisfactory because the volume changes in one finger proved too slight to give satisfactory readings. In 1895 Mosso[4], a pupil of Marey's, used the same principle to construct a *laboratory sphygmomanometer (Figure 12). By utilizing the cumulative* volume changes in four fingers simultaneously, Mosso was able to obtain satisfactory oscillations. His device was considered to give fairly

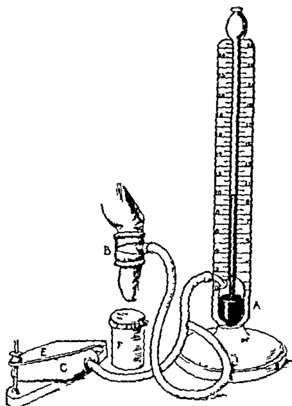
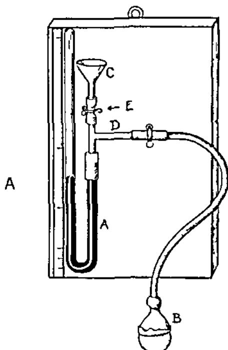


Fig 13.—Gartner Tonometer (1899)

A—mercury manometer. B—pneumatic cuff encircling finger. C—bulb. E—screw device to compress bulb. F—finger rest.

Pressure at which a flush or pulse returns to the bloodless finger is taken as the index of systolic pressure.

accurate readings and was employed for a long period of time but because it was so cumbersome it remained as a laboratory procedure. In 1899, Gartner[5] (Figure 13) introduced his "Tonometer," which also involved the principle of blood pressure measurement in the digital arteries. It was much more compact than Mosso's instrument and because it could be easily applied it gained fairly wide popularity for a



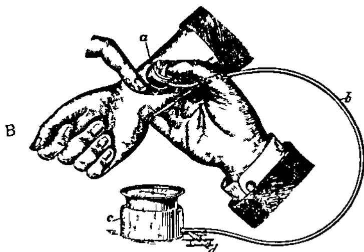


FIG 14*A*—VON BASCH SPHYGMOMANOMETER (1876)

A—mercury manometer B—pelote consisting of glass funnel with membrane distended with water C—glass funnel to introduce water E—pinchcock D—tube

First practical device for clinical measurement of blood pressure—systolic only

FIG 14*B*—IMPROVED VON BASCH SPHYGMOMANOMETER

a—pelote b—connecting tube between manometer and pelote still filled with water c—metal manometer

short period of time The point at which a flush returned to the bloodless finger, or the moment when pulsations were felt by the patient was considered to be a measure of the systolic pressure These instruments all had the disadvantage of measuring the pressure only in the small blood vessels of the finger As is well known these small blood vessels are readily subject to vasomotor changes, and variations in pressure within

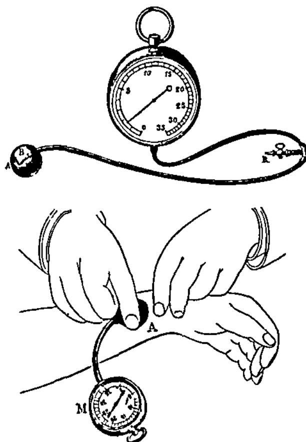


Fig 15 — Potain Sphygmomanometer (1889)

A—pelote consisting of a rubber cushion 3 × 2 5 cm filled with air B—thin part put directly on arterial wall M—anaeroid manometer R—valve connected to rubber bulb

Modification of Von Basch sphygmomanometer but portable and utilizing the *first anaeroid manometer*

them may occur as a purely local manifestation For this reason these instruments proved unsatisfactory and were soon discarded

Although Marey was the first to measure blood pressure in man with reasonable accuracy by indirect methods his method was too complicated

for practical clinical work and it remained a laboratory procedure. The first to make indirect blood pressure readings a clinical practical procedure in man was von Basch,[6] a Viennese physician, who will always be remembered as the inventor and father of clinical sphygmomanometry. In 1876 he constructed an apparatus that utilized a pelote originally consisting of a glass funnel covered with an elastic membrane connected with a reservoir and with a mercury manometer (Figure 14A). The pelote and tubing were filled with water from the reservoir and the zero point of the manometer was determined after the mercury came to equilibrium. The mode of application was as follows: An artery which lies directly upon bone such as the temporal or radial is selected and pressure exerted upon it with the membrane of the pelote. The pressure thus exerted on the artery is transmitted through the water filled system to the mercury manometer. The pulse is simultaneously felt with a finger of the opposite hand just beyond the point of compression. At the moment when the pulse disappears or when it first returns as the pressure is decreased the manometer is read—this is the systolic pressure.

Although the von Basch sphygmomanometer could be used clinically it had the disadvantage of being rather bulky and cumbersome. This objection was partially overcome by von Basch when he replaced the mercury manometer with a more compact metal manometer in 1890 (Figure 14B). However, water was still used to fill the system.

In 1889 Potain[27] modified the von Basch instrument making it much more compact and portable (Figure 15). He replaced the crude pelote von Basch had employed with a rubber cushion 3 × 2.5 cms and replaced the water with air; the pressure in this system could be raised by a rubber bulb. Potain was the first to employ an aneroid manometer. As a result of these modifications the Potain sphygmomanometer fitted easily into a small compact box which could be readily carried by the physician on his calls to the home and hospital. Von Basch's and Potain's machines became widely known and were employed clinically for a long time. Their method, however, had several disadvantages. The amount of tissue surrounding the artery and the quality of the arterial wall were variable factors which could influence the level of the blood pressure. Besides, the experience and ability of the individual physician in applying the proper technique was an important consideration in obtaining accurate readings. Potain himself warned that a frequent source of error arose from an inability to distinguish between the capillary pulse of the physician's finger and the pulse of the patient. For these reasons blood pressure (systolic only) obtained with this type of apparatus were not very accurate and were usually too high.

In 1896 a marked advance in clinical sphygmomanometry was made by Riva Rocci,[5, 8] who was professor of medical pathology at the University of Padua. The apparatus he devised is the forerunner of the modern sphygmomanometer (Figure 16). The important feature was

the introduction of a compressing mechanism, consisting of a rubber tube or bag 5 cm wide which encircled the middle of the upper arm and was inflated by means of a hand bulb The rubber bag was connected with a mercury or anaeroid manometer The radial artery was simultaneously palpated at the wrist At the instant before the oscillations disappeared, the level of the systolic pressure was read on the manometer This method had the advantage of applying the pressure in a more even manner over a wide area without the difficulties involved in the direct obliteration of the radial artery necessitated by the Potain von Basch and other instruments

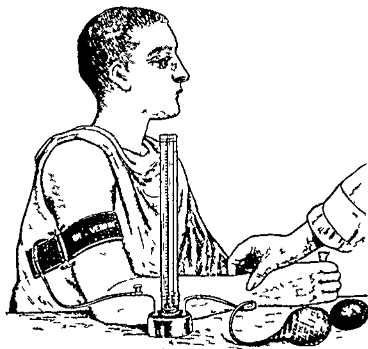


FIG 16 —RIVA ROCCI SPHYGMOMANOMETER (1896)
In principle the model used at present The narrow 5 cm armlet was later replaced by a 12–14 cm cuff

A year later 1897 Hill and Barnard[30] brought forth a sphygmometer similar in principle to that of Riva Rocci (Figure 17) An aneroid manometer was attached to the encircling cuff Movements of the needle of this delicate metal manometer considerably magnified the oscillations of the pulse wave As the criterion for blood pressure measurement Hill and Barnard recommended the mid point of the maximum oscillation of the needle which they thought corresponded to the mean blood pressure

However Janeway[35a] and others later suggested that the lowest point at which the maximum oscillation of the needle occurred was the diastolic pressure The method of Hill and Barnard is the forerunner of the more modern oscillometric methods which employed a wider cuff and more accurate recording methods *e g* Erlanger s sphygmometer[31] (1904) and Pachon s oscillometric sphygmometer[37] (1909)

In 1901 von Recklinghausen[33] pointed out that the readings obtained were about 10 per cent too high when a 5 cm wide armlet was used He introduced the 12 to 14 cm wide cuff which is employed today and which gives accurate readings

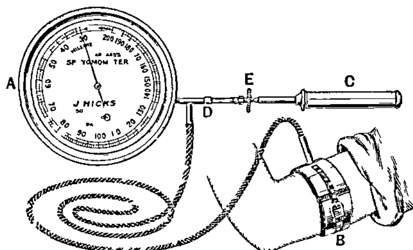


FIG 17 —HILL AND BARNARD SPHYGMOMETER (1897)
A—sensitive anaeroid manometer B—5 cm wide armlet C—inflating pump E—valve for slow escape of air
Point of maximum oscillation is used as the measure of diastolic pressure

Many instruments using the wide cuff connected to a manometer have been described by different investigators each making some modification of the same principle *e g* Stanton[34] Janeway[35b] Erlanger[31] Cook[36] etc With all of these the systolic pressure was recorded when the radial pulse disappeared at the wrist and the diastolic pressure when the lowest point of maximal oscillations of the pulse occurred The instrument devised by Erlanger (Figure 18) although cumbersome and complicated in its construction was considered to be one of the most accurate in the measurement of the blood pressure The point of disappearance or return of the pulse and the point of maximum pulsation were made so clearly visible that subjective errors were minimized

These methods were used until the auscultatory technique became known and generally employed This technique was first described in

1905 by Korotkow,[37] a Russian physician in St Petersburg With the bell of a stethoscope applied over the artery below the compressing cuff four distinct phases of sound can be heard and clearly differentiated, phase I the sudden appearance of a clear faint tapping sound, growing gradually louder phase II, the sound assumes a hissing murmurish quality phase III the murmur disappears and the sound becomes clear and louder phase IV the sound suddenly becomes muffled and phase V the sound disappears Korotkow suggested that the systolic pressure

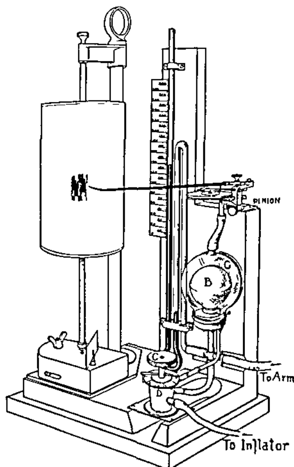


Fig 18 — Erlanger's Sphygmomanometer (1904)

The instrument is connected to the encircling cuff on arm Pressure in the system is gradually increased by the inflator and its level is indicated on the mercury manometer Arterial pulsations are transmitted through the thin rubber bulb (B) enclosed in glass case (C) to the writing arm and is inscribed on the kymograph A complicated but very accurate instrument to measure the blood pressure

be recorded at the very beginning of the first phase and that the diastolic pressure be recorded at the end of the fourth phase, *i.e.*, when the sounds disappear. Many investigators[34–4] found that the beginning of the fourth auscultatory phase (when the sounds become muffled) corresponds to the diastolic pressure found with the oscillometric method (when a sudden drop in maximal oscillation occurs). They therefore concluded that the diastolic pressure reading should be recorded at the beginning of the phase IV. Using the same techniques, however, others[43–4] found the oscillometric diastolic pressure corresponds to the beginning of the fifth auscultatory phase. In 1939 the Committee on Standardization of Blood Pressure Readings of the American Heart Association and of Great Britain and Ireland[46] recommended that the point of muffling of the sounds (beginning of phase IV) be accepted as the diastolic pressure. When the level of disappearance of the sound is lower than the level when the change occurred, that level also should be recorded, *e.g.*, 140/70–40 mm mercury. Very recently, however (1951), The Council For High Blood Pressure Research of the Scientific Council of the American Heart Association through the Committee to revise Standardization of High Blood Pressure Readings concluded that the point of complete cessation of the sounds is the best index of the diastolic pressure.*

Under hemodynamic conditions in which no cessation of sounds occurs, the point of muffling should be taken as diastolic pressure if distinctly heard and should be recorded as the point of muffled sounds. When no clear demarcation of the muffling is heard, diastolic pressure should be left indefinite and so indicated, *e.g.*, 150/30?

The recommendations formulated in 1939 contained the suggestion that two values for diastolic pressure be recorded, *e.g.*, 140/80–70. It is the impression of the Committee that such a practice has not been followed very generally. It doubts, on the grounds of hemodynamics, the propriety of listing two figures as "diastolic pressure". The disappearance of auscultatory sounds as a criterion of diastolic pressure is recommended on the following grounds:

(*A*) The current practice of using the point of sudden muffling of the sounds was based (1) on comparisons with oscillatory criteria and (2) on hemodynamic data derived from studies of excised or isolated arteries undergoing direct compression or decompression. The former (1) is of dubious value since no general agreement has been reached regarding the oscillatory criteria of diastolic pressure. The latter (2) appears to be risky owing to the fact that unsolved physical factors may enter when pressure is transferred to arteries from a cuff of arbitrary size through the tissues of a limb.

* From "Recommendations for Human Blood Pressure Determinations by Sphygmomanometers" by James Bordley III, M.D., Charles A. R. Connor, M.D., W. F. Hamilton, M.D., William J. Kerr, M.D. and Carl J. Wiggers, M.D. Circulation 4, 503, 1951.

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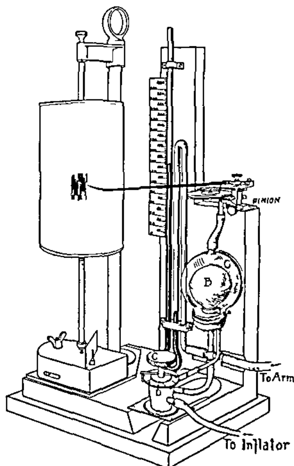


Fig 18 —Erlanger's Sphygmomanometer (1904)

The instrument is connected to the encircling cuff on arm Pressure in the system is gradually increased by the inflator and its level is indicated on the mercury manometer Arterial pulsations are transmitted through the thin rubber bulb (B) enclosed in glass case (C) to the writing arm and is inscribed on the kymograph A complicated but very accurate instrument to measure the blood pressure

TABLE I —CHRONOLOGIC EVOLUTION OF THE TECHNIQUE OF BLOOD PRESSURE MEASUREMENT

Date of Invention	Name of Inventor	Principle Involved
1733	Hal	Pressure ind cat d by blood l l n a tube connected to artery of an mal
1828	Poiseu ll	Introduced U form of me cury man met
1834	Hérri on	Devised first phygmomete ob rved ampl tude of arterial pul t ons n man
1847	Ludw g	Conne t d fl t and writing arm to Poiseuille manom ter for th d t egist at on of blood pressure
1850	M gend e	Mod fi d and improved the Po eu lle manometer
1855	V erordt	Sy tol c blood p ssu n man m u d nd rectly by weight requ d to obl t t d al pulsations
1860	Marey	Devis d a ompact sphygmograph eas ly attach d to forearm
1867 1868 1872 1875 1896	Foste B hier Landoi *Waldenbu g* Ph lad lph n	U ed Vier) dt p n pl w th M y s sphygmograph to mea u) tol p ssur
1875	Ma ey	P u appl d to nt ad l a t y by enclos ng for arm in a m tal bo Le l of m mal arterial pul at on nd blanch ng of sk n tak n as nd ces of blood p u
1878	Ma ey	F nger pl thy mog aph employe l t measu the blood p ssu Same prin pl as abo e but appl ed to one fing only
1876	Von Ba h	F t p act cal l n al phygmomanometer Util zed p nc ple f local comp ess on of art ry t ll pul at n di app a d
1888	Bloch	A ve t pock t sphygmom t Measured amount of local p e su qu d to obl te at ad al pulsat ons
1889	Pota n	Imp ed th von Basch sphygmom nom t U d first ana o d manom t
1895	Mo o	Mea u d d gital a t y p u by r g tering volum hanges n 4 finger s multaneou ly
1896	R va Roc	Employ d i cula omp n of upper rm w th a 5 m w d rubb b g Fo tunn of mod n sphygmomanometer
1897	Hill & Barn d	Sam p ncipl as abov but used metal m nom te d employ d o c llom tr m thods
1899	Gä tne	M asu d y tol p u of d g tal rteri by tonomet
1901	Von R kl nghau en	Int oduced wid 12 14 cm uff
1903 1903 1904 1904	Stanton C k J n w y E l ng	Ame ic ns who were amo g the first to mploy pr cti al d vices f bl od p u m asur ment
190	K rotk w	Introdu d auscultatory techniqu

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Chapter II

HISTORY OF BLOOD PRESSURE EVOLUTION OF NORMAL LIMITS

ABOUT 30 000 years ago the Cro Magnon race lived throughout Western Europe They were apparently intelligent and keen observers and the signs of their artistic skill and power of observation are visible today in paintings on the walls of the caves in which they lived One of these paintings[47] was found in the cavern of Pindal (Asturias-Spain) (Figure 19) The primitive artist drew the outline of a mammoth in red ochre, and in the center of it he placed a dark spot that may represent the heart Sigerist[48] in his excellent history of medicine makes the following comments regarding this drawing the organ (the heart) must have attracted the attention of man from the earliest time because he found it beating as long as there was life because he soon must have discovered that the best way to kill an animal was to hit it through the heart and perhaps also because he felt his own heart hammering in the breast when fear seized him If the dark spot of the mammoth of Pindal actually represents the heart we may well consider this the earliest anatomical picture

An understanding of the circulation of the blood in the body necessarily preceded the study of the blood pressure Although the history of blood pressure measurement is comparatively recent, some newer paleographic discoveries have indicated that the history of the circulation begins as long as four or five thousand years ago Even at that early time the observations about many of the phenomena of the circulation were remarkably accurate though the interpretation of these observations was often inaccurate and full of fantasy

Egypt can be considered the cradle of human civilization The prosperity of Egypt rightly called by Herodotus a gift of the Nile was the result of the knowledge of the Laws of Hydraulics which the Egyptians possessed About 5000 years ago they constructed a network of canals which brought the water and mud from the Nile to the remotest places and transformed the desert into a flourishing countryside

Medicine kept pace with other branches of human knowledge in ancient Egypt and must have been a widespread specialized art Herodotus[49] in his second book says Medicine with them is distributed in the following way Every physician is for one disease and not for several and the whole country is full of physicians for there are physicians of the eyes others of the head others of the teeth others of the belly others of

obscure disease Egyptologists[50] are inclined to assume that medical science was very highly developed in the Old Kingdom (2500 B C) so that no physician could master it, specialization in consequence was unavoidable then as it is today

A few Papyri dealing with medicine (Smith Ebers Hearst and Berlin)[48b] have recently been unearthed They tend to show that the ancient Egyptians were truly aware of the importance of the heart and peripheral circulation They *are a collection of monographs*, each devoted *to a*

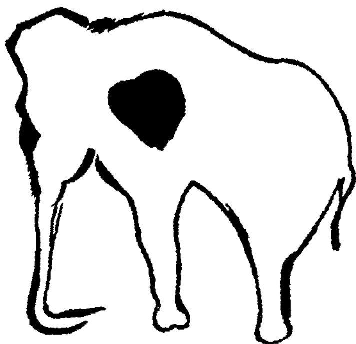


FIG 19 – MAMMOTH WITH HEART

Silhouette drawn by a primitive artist in a cavern—Pindal (Asturias Spain) approximately 30 000 years ago Red ochre was employed for the entire design The color is still brilliant The red spot on the mammoth apparently represents the heart (Picture reproduced from H Kuhn Malerei der Eiszeit Delphin Verlag Munchen 1922 p 42)

particular subject – the Smith and Ebers Papyri were written at the beginning of the XVIII dynasty (about 1600 B C) Both are copies of much older texts *that may go back to the Pyramid Age* (2600 2000 B C)[48c] *The longest most interesting and most important is the* Ebers Papyrus (20 23 meters long) said to have been written about 1600 B C *In it, there is a long treatise on the physiology of the circulation in which* the mutual relationship between the heart and vessels is clearly described This begins with the caption The Physician s Secret Knowledge of the Heart s Movement and Knowledge of the Heart

(Ebers)[48d] From the following quotation it is obvious that the Egyptians had some understanding of the circulation of the blood and were well versed in the art of pulse palpation If the physician places[48] ' the hands or his fingers to the head to the back of the head to the hands to the place of the stomach to the arms or to the feet, then he examines the heart because all his limbs possess its vessels that is the heart speaks out of the vessels of every limb ' His heart beats feebly [48] was an alarming symptom for an Egyptian physician feeling the weak pulse of a patient It is interesting that in the Ebers Papyrus the pulsations in the vessels are compared to the ebb and flow of the Nile [51] The ancient Egyptians therefore must have been deeply impressed with the vital importance of the circulatory system to have compared it with the tide of the Nile for they considered the Nile and its tides to be one of the most majestic and important natural phenomena of their time

As is emphasized by Grapow [52] one of the recognized experts in Egyptian medicine the basic idea was that in the normal human body there is a system of vessels originating in the heart and connecting it with all other parts of the body These vessels supposedly carried air liquids such as blood urine tears sperm and solid matter such as feces the heart being the center and pumping force of this system of distributing vessels It seems logical that this concept of circulation of fluids and solid matter in the body was applied also in pathology (Berlin Papyrus) because they knew through their own experience that their land suffered when the canals bringing the Nile water were out of order just as disease resulted when canals of the human body did not function as they should [48d] This wonderful observation which brought the Egyptians so close to the discovery of the circulation [53] remained dormant for many centuries

The art of mummification perfected in ancient Egypt enabled the priestly embalmers to become acquainted with the internal structure of the human body It is of interest to note that during the process of embalming the heart and kidneys were the only internal organs that were carefully left *in situ* suggesting that the heart was considered to be essential to the individual not only during life but even after death

Since the peripheral pulse could be readily palpated and observed it was the one phase of the circulation which impressed many ancient physicians A good deal of time and attention was devoted to the pulse [51] and many long descriptive treatises were written about it In ancient Chinese writings (1123 to 256 B C) at least 23 varieties of the radial pulse were described Many of the observers were aware of the importance of various qualities of the pulse hard and soft pulses were long identified with certain diseases Thus in 200 B C Choven You Y [54] wrote that kidney disease is present when the pulse is hard and very difficult to obliterate by superficial palpation! Although attention was paid to the force of the pulse its correlation with the pumping force of the heart was not considered

The ancient Greeks also accumulated much information about the pulse but their detailed observations were frequently misinterpreted They believed, for example, that the heart and vessels contained air rather than blood As early as 310 B C Herophilus, considered the Father of Anatomy proved the synchronicity of the arterial pulse with the beat of the heart and attributed to the pulse four main qualities size frequency, *force* and rhythm However the Greeks too, did not understand the relationship between the pumping force of the heart and the beat of the pulse Galen (131–201) much later showed that the vessels contained blood and demonstrated the motor power of the heart by the pulsation of blood which occurred between the heart and the point of ligation of an artery



Fig 20 — William Harvey (1578–1657)

Portrait by William von Bemmel (1698–1780) engraved by Jacob Houbraken (1739) This portrait was in possession of Sir Francis Millman M D (1746–1821) and Richard Bright (1789–1858) the famous physician discoverer of the kidney condition called Bright s Disease[55]

This observation of Galen s lay dormant until Harvey s (Figure 20) classical work was published in 1628,— Exercitatio anatomica de motu cordis et sanguinis in animalibus (Anatomical Exercise on the Motion of the Heart and Blood in Animals) (Figure 21) This was subsequently translated and published in English in 1653[56] Harvey elucidated the

EXERCITATIO

ANATOMICA DE MOTV CORDIS ET SANGVINIS IN ANIMALIBVS,

GVILIELMI HARVEI ANGLI

Medici Regii, & Professoris Anatomiæ in Collegio Medicorum Londinensi.



FRANCOFVRTI,

Sumptibus GVILIELMI FITZERI.

ANNO M DC. XXVIII

FIG 21 —Frontispiece of the famous treatise on the physiology of the circulation published by W Harvey

The text is in Latin and printed in Frankfurt (Germany) Twenty five years later it was translated into English and published in England

mechanics of the circulation and proved the central propulsive action of the heart which in the nature of a force pump propels the blood along the vascular channels in a continuous cycle He stated that the pulsation of the arteries arises from the impulsion of the blood from the left ventricle also according to the tension of the heart the pulsations are greater more vehement

A hundred years or more had passed before Stephen Hales[1] (1733) measured the intra arterial blood pressure for the first time He expressed the pressure in terms of the weight of the blood itself His measurements of the blood pressure in various animals —sheep dogs horses etc — were amazingly accurate Hales estimated the blood pressure in man to be about $7\frac{1}{2}$ feet of blood This corresponds to about 176 mm of mercury Despite the crudeness of this method and the limitation of his work to experimental animals this estimate was indeed remarkable

In 1856 the first accurate blood pressure measurement in man was done by Faivre[58] a French physician from Lyon He connected the Poiseuille manometer directly with the lumen of a large artery in three patients prior to the amputation of a limb In two cases the pressure was measured in the upper part of the brachial artery in the third case it was measured in the femoral artery In each instance the pressure was found to be about 120 mm mercury As a result of his observations Faivre thought that this was the mean aortic pressure in man

The determination of what constitutes the normal blood pressure was early recognized as a problem of great importance Sanderson[57] in his monograph on the clinical value of the sphygmograph published in London in 1867 places the normal arterial pressure at six or seven inches of a column of mercury (152 179 mm mercury) He however does not describe the method he used to obtain this measurement It depended on the development of suitable devices which could measure the blood pressure by indirect means The first of such measurements which were performed by Vierordt Behier Landois and others were grossly inaccurate being about two to ten times higher than the true level and were therefore of no value in establishing true normal limits The first book devoted to blood pressure Die Messung des Pulses und des Blutdrucks am Menschen —was written by Waldenburg[17] in Berlin and published in 1880 It directed attention to the importance of the blood pressure in clinical medicine On the basis of studies of twenty nine healthy persons between the ages of seventeen and sixty five years he too set limits of 200 to 260 mm mercury These high values are the result of his inaccurate technique and are only of historical interest

Von Basch[6] is considered to be the father of clinical sphygmomanometry since he introduced the first practical device to measure the blood pressure Following its introduction in 1876 it was employed by a number of physicians in clinical practice Using von Basch s apparatus

Zadek[59] in 1881 published a long and comprehensive report on his findings. As a result of measurements done on a number of healthy men and women he concluded that the upper limit of the normal pressure was 150 mm mercury and that the lower limit was 70 mm. How close his figures are to those commonly accepted today! He also pointed out that the blood pressure was lower in children, that it increased after meals, in the afternoons, following exercise and in high altitudes and that it usually decreased with rest. These were indeed remarkably accurate clinical observations. Von Basch[60] himself in a series of five articles in 1887 summarized his own experience with his apparatus as well as that of other investigators. He predicted the very important

TABLE II.—BLOOD PRESSURE IN 276 HEALTHY INDIVIDUALS—THAYER (1904)

Age	Average Systolic Pressure (mm mercury)	Number of Cases
1–10	104.6	37
10–20	128.7	87
20–30	136.9	89
30–40	140.8	37
40–50	142.2	20
50–60	154.8	5
60–70	180	1

role that blood pressure measurements would play in the future of medicine. His conclusions were that the normal blood pressure was 110 to 160 mm mercury in the radial artery and 90 to 120 mm in the temporal artery. Von Basch preferred to take the pressure in the latter vessel.

With the introduction of the Riva Rocci apparatus in 1896 a new impetus was given to the measurement of blood pressure in clinical medicine. Many workers in different parts of the world employed this technique and each set forth what he considered to be normal values—Gumprecht[61] (1900), Hensen[6] (1900), Hayaski[63] (1901), Cook and Briggs[36] (1903), Thayer[64] (1904). However their values were about 10 per cent too high because of the narrow 5 cm armlet which was used. Their observations also were made on only a small number of normal individuals and were therefore of very limited value. It is interesting to note that one of the first men to use the Riva Rocci apparatus in the United States was the famous neurosurgeon Harvey Cushing.[6] While visiting in Pavia he was impressed by this apparatus and recognized the value of blood pressure measurements in surgery. As early as 1902[66] he published an article on the importance of the blood pressure level during operative procedures as determined by the Riva Rocci instrument. In 1903 Cook and Briggs[36] of Johns Hopkins University wrote one of the first extensive articles to appear in the American literature

on the measurement and clinical interpretation of blood pressure. They analyzed the blood pressure findings in a series of normal, surgical, obstetrical and medical patients and stressed the importance of blood pressure measurements in clinical practice. In an article published in 1904, Thayer[64] found that there were still insufficient data available on blood pressure in the normal population. In order to assess his findings in a series of old typhoid patients, he had to measure the blood pressure in 276 normal individuals in an attempt to establish a normal level. His data (Table II) are representative of the findings of various authors between 1900 and 1904 who employed the Riva-Rocci apparatus with a 5 cm. armlet.

Potain,[67] a brilliant clinical observer, published little of his findings on blood pressure measurement during his lifetime. In 1902 he collected the results of thirty years of study, entailing 11,000 blood pressure readings, and wrote the first extensive work on blood pressure and its limits. His book, published two weeks after his death, was entitled La Pression Arterielle de l'Homme. Although his readings today are considered too high because of the technique he employed, his book has great historical interest. In it Potain emphasized the importance of three major factors in the determination of the blood pressure level: 1) the function of the heart, 2) the peripheral resistance of the arterioles, which he considered the most important factor, and 3) the quality of the arterial wall. He stressed the effect of age on the normal range of the systolic pressure, and investigated extensively the effects of various other factors such as weight, sex, activity, altitude and fever.

The following is a summary of the results obtained by Potain on normal individuals:

TABLE III.—AVERAGE SYSTOLIC PRESSURE

Age	(mm. mercury)	Age	(mm. mercury)
6-10	89	30-40	190
10-15	135	40-50	200
15-20	150	50-60	210
20-25	170	60-80	220
25-30	180		

Although the readings are high because of the method of measurement he used, the increase in the blood pressure with increasing age which he found is certainly striking.

In the years between 1901-1904 Janeway,[68] Masing[69] and Sahli[70] endeavored to measure the diastolic pressure by means of the oscillometric method. As the pressure in the encircling arm cuff was slowly decreased, the lowest point of maximal oscillation of the radial pulse was taken as the diastolic pressure, the oscillations being recorded on

a sphygmograph The readings were much higher than those obtained with the auscultatory method which was later introduced by Korotkow

Following the introduction of the wide 12 to 14 cm armlet by von Recklinghausen in 1901 and the institution of the auscultatory technique for blood pressure measurement by Korotkow in 1905 the era of modern clinical sphygmomanometry began The evolution of the present day normal blood pressure limits dates from this time

In 1904 Theodore C Janeway[3] in a monograph entitled The Clinical Study of Blood Pressure gave the upper limit of normal systolic pressure as 160 mm mercury In 1913 on the basis of the experience derived from the blood pressure measurements in 7 872 cases done by his father and himself Janeway[71] again stated that a pressure over 160 mm mercury may be considered abnormal Brunton[2] (1910) in England and Cook[73] (1911) of Johns Hopkins lowered this limit to 135 mm up to middle life and to 145 to 150 mm thereafter In 1915 Janeway[74] revised his former opinion and accepted these standards Although he recognized the importance of the diastolic pressure he did not have sufficient data to establish its normal limits At that time Janeway was a pioneer and probably the highest authority in the United States in this field The results of his investigations and publications undoubtedly had an important influence on the establishment and acceptance of these blood pressure limits as normal

The present commonly accepted normal limits of blood pressure have been established largely through studies by life insurance companies in the past four decades With the introduction of the sphygmomanometer and its regular use in life insurance examinations vast numbers of blood pressure readings on men and women at various ages have been accumulated The data thus obtained have been analyzed statistically from time to time and the average blood pressures in men and women at various ages have been thereby determined Fisher[75] of the Northwestern Mutual Life Insurance Company in 1914 was one of the first to publish the results of blood pressure measurements on 19 339 accepted candidates for life insurance Subsequently a large number of similar studies was issued[76–8] — Symonds Rogers and Hunter MacKenzie and Wells and others Representative findings of the insurance company studies are shown in Table IV The conclusions of Symonds are based on the examination of over 160 000 applicants while those of Hunter are based on the examination of a quarter of a million applicants

According to the insurance company statistics the *average* blood pressure increases very little with age the systolic pressure increased from 12 to 22 mm mercury between the ages of fifteen and sixty five while the diastolic increased from 8 to 14 mm mercury

Symonds also found a difference in the blood pressure in the two sexes In women below the age of forty he reported the systolic pressure to be slightly lower than in men after forty he found it slightly higher (1 to

2 mm mercury) The diastolic pressure in women below forty was slightly lower (1 mm mercury) than in men but over fifty it was higher

Fisher was the first to find that a persistent increase of 15 mm in the auscultatory systolic pressure above the average for the age (Table IV) resulted in an unexpected rise in the mortality rate Hence he concluded that an increased systolic pressure of 15 mm or more from the given

TABLE IV —AVERAGE BLOOD PRESSURE OF INSURANCE APPLICANTS

	Symonds (160 000)		Hunter (50 000)	
Ages	Syst	Diast	Syst	Diast
15–19	123	9	113	75
20–24	124	80	120	80
25–29	124	91	122	81
30–34	125	82	123	82
35–39	125	83	124	83
40–44	126	84	126	84
45–49	128	85	128	85
50–54	130	86	130	86
55–59	133	87	132	87
60 & over	135	8	135	89

average should be regarded as pathological His conclusion was corroborated by the statistical findings based on mortality rates of other life insurance studies and was accepted by many investigators (Symonds Rogers Hunter and others) MacKenzie[86] suggested that the normal systolic pressure limits be set at 95 to 135 mm mercury for fifteen to nineteen year old applicants and that they be progressively increased (110–155 mm mercury) until after the age of sixty

Regarding the diastolic pressure Fisher believed that a pressure above 90 mm in patients under the age of forty and one above 95 mm in patients over forty were abnormal Symonds thought that any diastolic pressure above 94 mm was probably abnormal MacKenzie using the 5th auscultatory phase as the index considered a diastolic pressure of 60 to 85 mm mercury to be normal for the fifteen to nineteen year age group and one of 65 to 100 mm mercury to be normal for those over the age of sixty Rogers and Hunter placed the diastolic limit at two thirds of the systolic

On the basis of these insurance company studies the present commonly accepted normal limits of 140 to 150 mm mercury systolic and 90 to 95 mm diastolic have been accepted by many authorities Alvarez[87] Fishberg[88a, b] Wiggers[89] White[90] Friedberg[91] and others Robinson and Brucer[92] in a widely quoted investigation however set the normal

upper limit of blood pressure at 120 mm systolic and 80 mm diastolic regardless of age and sex As will subsequently be shown these limits are unacceptable

ESSENTIAL HYPERTENSION

Simultaneously with the evolution of normal blood pressure limits came recognition of the hypertensive state and of its effects upon the cardiovascular and renal systems The gradual awareness of the hyper tensive state as a distinct entity further served to stress the importance of establishing limits of normal blood pressure The historical evolution of the concepts of hypertension and of normal blood pressure are rather closely integrated Many early physicians were aware of the importance of increased blood pressure in man Its presence was discovered long before methods to measure it were available Careful study and obser vation led some of the early clinicians to recognize in some patients the increased tension and hammering pulsations in the peripheral arteries Ludwig Traube[93 94] was the first to describe increased arterial tension in man In 1856 he published some of his clinico pathological studies among which he reported the case of a forty year old physician in whom he found the arteries of middle caliber to be definitely under tension Thus he realized at the bedside by palpation of the arteries that a state of increased intravascular pressure existed

Following Bright s[9] classical description of the disease that bears his name it was commonly felt that increased arterial tension was always a consequence of pre existing renal disease or arteriosclerosis Much later it was discovered that hypertension may be the primary disturb ance and may antedate the development of arteriosclerosis and renal disease Sanderson[57b] was one of the first to suggest that arterial hyper tension may exist before manifest clinical signs of kidney disease appear In 1867 in a monograph on the clinical value and use of the Marey sphygmograph he described two patients with postmortem evidence of left ventricular hypertrophy and Bright s disease During life both patients had had bounding visible pulses the arteries knocking against the finger like a hammer Sanderson emphasized the value of the pulse tracing obtained with the sphygmograph in providing evidence of the presence of increased arterial pressure in these cases He suggested that the sphygmograph be used to detect increased arterial tension in patients with no other clinical evidence of left ventricular hypertrophy and kidney disease He believed that many persons have a high tension pulse without any other trace of ailment and that the arterial resistance in them is excessive but he did not have enough experience to understand the significance of this finding Though clinical sphygmomanometry had not yet been developed Sanderson pointed out the importance of the sphygmogram as an objective method of detecting early cases with

increased arterial tension before the appearance of heart and kidney disease

Several months before Sanderson s monograph appeared, Foster published a booklet on the same subject [96] Using the Marey sphygmograph on a man of 37 he demonstrated a pulse tracing which was typical of *strong tension in the arteries* Foster stated that this condition can easily be recognized by the form of the pulse tracing He was very enthusiastic about the clinical use of Marey s sphygmograph as an objective method for detecting what he called ' senile changes in the arteries in its early phase *i e* when the diagnosis cannot be established by palpation of the arteries He explained the frequent coexistence of hardening of the peripheral arteries* and left ventricular hypertrophy in elderly people by the necessity of the heart to act more forcibly in order to carry on the circulation of the blood

The presentation of Foster s and Sanderson s publications to the English medical profession aroused great interest at that time English physicians were aware of the importance of recognizing the presence of high blood pressure and other conditions detectable through the sphygmograph A controversy arose among them as to who should be considered the first to have employed Marey s sphygmograph in clinical medicine in England From a survey of the exchange of letters published in The Lancet *at that time* [100, 101] *it seems now that Burston Sanderson* his collaborator Francis Anstie and Walter B Foster can all share this honor

Mahomed [102, 103] an English pupil of Marey s enlarged on Sanderson s observations and suggestions Using the sphygmograph in a large number of cases he also found that an increase of arterial pressure may precede the appearance of symptoms of renal disease He termed this the pre albuminuric stage of Bright s disease In 1874 he stated Previous to the commencement of any kidney changes or the appearance of albumin in the urine the first condition observable is high tension in the

* *It is interesting to note that arteriosclerosis is a process which can be traced far back in the history of man* Ruffer [97] the founder of Paleopathology (the pathology of ancient specimens) in his classical work "Studies *in the Paleopathology of Egypt demonstrated that old Egyptians suffered also from arteriosclerosis of the aorta and peripheral vessels* He presents clear preparations from specimens of the aorta and arteries from mummies revealing the same picture as that found in modern material Atheromatas atheromatous patches and ulcers more or less completely calcified King Mernepteh [9] the Pharaoh of the Hebrew exodus suffered from arteriosclerosis of the aorta Moodie [99] with the aid of x rays could demonstrate sclerotic vessel in an unwrapped mummy in the Field Museum in Chicago

The opinion that arteriosclerosis is a disease of modern times and is related to modern nutrition and the physical and mental strains of modern life is evidently contradicted by these clear objective findings

arterial system ' Mahomed did not yet disassociate the two conditions but felt that the hypertension always represented an early stage of Bright s disease In a later article in 1879 however Mahomed expressed doubt concerning the absolute relationship between increased blood pressure and Bright s disease for he wrote I have tried to prove that the high arterial pressure and the subsequent cardiovascular changes are the primary and most important conditions to recognize while the kidney symptoms are only secondary and are not even essential conditions He was one of the first to be aware of the existence of increased arterial tension in the absence of kidney disease and of the importance of its effects on the various systems of the body His deductions are most impressive since they were made without actual measurement of the arterial blood pressure

Von Basch [104] using the first practical sphygmomanometer which he devised also realized that hypertension may exist in the absence of nephritis and demonstrable arteriosclerosis He attributed the high blood pressure in these cases to latent angiosclerosis It was not until 1895 that Sir Clifford Thomas Albutt[10] clearly separated the syndrome of essential hypertension from Bright s disease He described in detail his long and careful observation of patients with essential hypertension and concluded that they did not necessarily develop renal disease In a paper read before the Hunterian Society in London he stated ' I had begun to recognize that rising pressure did not necessarily mean incipient stages of renal disease in the ordinary sense Albutt introduces the term hyperpiesia to describe these cases This term is still popular in England In America the term essential hypertension is widely used and is derived from the German essentielle Hypertonie introduced by Frank [106] in 1911

Huchard [107] in 1899 wrote a masterful description of the clinical picture of essential hypertension He pointed out that arterial hypertension is the cause of arteriosclerosis and precedes for a variable period the development of cardio renal involvement In 1914 Volhard and Fahr[108] differentiated between the benign and malignant forms of hypertension

SUMMARY

A brief historical review of the study of the circulation and of the blood pressure in man has been presented The development of the present commonly accepted limits of normal blood pressure—140–150/90–95 has been traced These were initially introduced by a few authoritative early workers in the field—notably Janeway Brunton and Cook It is however the life insurance company studies that are mainly responsible for the present day limits These studies have been based on an analysis of blood pressure readings on large numbers of applicants for life insurance

The normal limits have been established by an analysis of blood pressure findings in relation to the mortality rates A brief account of the historical evolution of the concept of essential hypertension has been presented

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Chapter III

FACTORS AFFECTING THE BLOOD PRESSURE LEVEL

MANY factors may affect the level of the blood pressure. True attempts have been made to standardize the technique of sphygmomanometry, for example, by committees of cardiologists from Great Britain, Ireland and America. The blood pressure of an individual is often found to vary. The variations are caused by one or more of the factors which may be active, and are in part responsible for the difficulties encountered when attempts are made to establish the upper and lower limits of the normal blood pressure. A discussion of some of these more important factors, therefore, and of their effects on the blood pressure seems to be necessary.

AGE

Many textbooks minimize the influence of age on the blood pressure.[216, 226, 90, 109] A systolic pressure of 140 to 150 mm. mercury and a diastolic pressure of 90 to 95 mm. mercury are usually accepted as the upper limits of normal in adults at the age of forty as well as in those at the age of sixty-five. Studies made on children,[110–114] however, have shown that the systolic pressure gradually increases with age. The increase is more marked at puberty and soon thereafter the blood pressure reaches adult levels. There is, in addition, overwhelming clinical evidence to indicate that there is normally a significant increase in the blood pressure in adults with increasing age. This normal increase has been found to be more marked after forty and to affect the systolic more than the diastolic pressure. The studies supporting this contention are fully presented in Chapter IV.

SEX

Relatively little attention has hitherto been paid to the influence of sex on the blood pressure, so that identical limits have been set for men and women. The pressure in females below the age of forty, however, has been found to be slightly lower than that in males, while in females over fifty it has been found to be somewhat higher. Because of these findings, no single figure can be accepted as the upper limit of the normal blood pressure. The age and the sex of the individual must, in all cases, be taken into account.

EMOTIONAL STATES

It has long been known that a nervous or emotional upset particularly fear may cause a transient increase in the blood pressure In 1899 Kapsamer[115] asserted that the true level of the blood pressure can be determined only after many blood pressure readings have been taken in order to avoid variations due to psychic factors Subsequently this observation was confirmed and emphasized by many others—Jellinek[116] Potain[7] Janeway[3,4] and Ehrstrom[117] This psychic effect on the blood pressure is apt to occur particularly at the time of the first medical examination for entrance into the military service for life insurance for employment or for routine clinical study

Diehl and Lees[118] measured the blood pressure of 100 unselected healthy students every five minutes for one hour They found a definite decrease in pressure on the second and third reading and a lesser decrease up to the eighth reading which was the lowest Thereafter the pressure rose slightly The gradual drop in the blood pressure was considered to be due to a gradual diminution of excitement of the subjects studied

Zabel[119] after having repeatedly determined the blood pressure of a great number of individuals found that only 15 to 20 per cent had a constant pressure level He felt that the psychic effect of the examination, which caused the blood pressure variations can be overcome only after at least 50 consecutive blood pressure determinations This suggestion is rather impractical and can only result in a rise of the physician s pressure Ayman and Goldshine[120] and others[121,122] compared the blood pressure in cases of essential hypertension taken at home and in the clinic and always found the home readings lower Since their observation of each patient was long continued it indicates the importance of the pressor effect exerted by the examining physician even after repeated visits Cannon[123] and others[124–126] showed that great excitement or pain increases the blood pressure Landis and Gullette[127] studying 25 young subjects found that by inducing such marked emotional changes as surprise fear and sexual excitement the blood pressure was increased Surprisingly anger and disgust produced practically no changes Scott[128] and others[129] recorded the blood pressure of 100 healthy men nineteen to thirty one years old during the exhibition of a special film designed to arouse the emotions of love sex fear and anger They found a definite rise in blood pressure as a result of sex stimulation and a lesser rise as a result of anger and fear

SLEEP

The effect of the emotions on the blood pressure has also been studied indirectly by recording it during sleep Howell[130] in 1897, was one of

the first to point out that the blood pressure drops at the onset of sleep as a result of the absence of psychic and emotional stimuli which affect the wakeful state Later others[131–134] confirmed Howell s findings

Muller,[135] and others [136] in an extensive study of 155 healthy individuals from three to ninety years of age (33 being children) found an average drop in blood pressure after one to two hours of sleep of 26 mm mercury in males and 21 mm in females In a study of 26 normal individuals Muller and Brown[137] found that the systolic blood pressure dropped till 3–4 A M and then rose slowly and steadily The diastolic pressure also dropped but much less markedly than the systolic MacWilliam[134] asserted that the systolic pressure may fall as much as 20 mm mercury during sleep However when the sleep is restless or is disturbed by dreams a considerable rise in both the systolic and diastolic pressure may occur

In hypertensives also the blood pressure falls during sleep Muller [13] in 25 cases of benign hypertension found an average drop of 60 mm mercury in the systolic pressure during sleep though the pressure still remained higher than normal In 18 cases of acute or chronic glomerulo nephritis the findings were similar but less marked The same results were given by other investigators [13, 137–139]

BASAL CASUAL AND SUPPLEMENTAL BLOOD PRESSURE

Addis [140] in 1922 first introduced the term basal blood pressure He applied this term to the pressure found in patients before they arose from bed in the morning He contrasted these low levels with those found later in the day The true basal blood pressure has been defined as the pressure present when all physical emotional and metabolic activities are reduced to a physiological minimum Such a reading is difficult to obtain The Committee of the Cardiac Society of Great Britain and Ireland and of the American Heart Association[46] have recommended the following procedure A preparation similar to that used in making a basal metabolism test is recommended Such a basal blood pressure determination should be made from ten to twelve hours after a previous meal (preferably in the morning) after the patient has rested for thirty minutes in a comfortably warmed room The patient should be mentally as well as physically at ease In addition Smirk[141–146] and co workers have stressed the need for deliberate emotional desensitization of the subject to the presence of the examiner and to the procedure of sphygmomanometry This desensitization is produced by taking the blood pressure as frequently as possible during the first three minutes after adequate preparation of the patient The pressure is then taken every few minutes for a half hour period in order to habituate the patient to the

procedure To allay apprehension the patient is placed in a comfortable position and is fully informed of what will be done The room is kept quiet, and unnecessary movements by the observer are avoided Using this procedure in combination with the one outlined by the Committee Smirk obtained lower blood pressure readings than when he used each method separately It is evident that many precautions must be taken in order to insure complete physical and mental rest for the patient if a true basal reading is to be obtained

The casual blood pressure reading represents the systolic and diastolic pressures obtained during the ordinary clinical examination without employing any special means to eliminate psychogenic factors which may affect it The difference in pressure between it and the basal blood pressure (called the supplemental pressure by Alam and Smirk[146]) is the result of physical emotional and supra basal metabolic activity Most of the supplemental pressure is of mental origin due especially to fear It is well known that a stay in a hospital usually produces an appreciable fall in the blood pressure of patients with essential hypertension This is the result of the physical rest of an increasing familiarity with the procedures used and of a more intimate acquaintance with the physicians Perera and Atchley[147] Watkin et al[148] and others have emphasized the importance of hospital environment in lowering the blood pressure and the necessity of considering this factor in determining the value of particular therapeutic measures It undoubtedly is of great importance to use basal readings when the effect of any therapeutic procedure on the blood pressure level is studied

To obtain a true basal blood pressure reading is obviously too time consuming and therefore impractical in daily clinical practice Hence the casual blood pressure obtained under ordinary clinical conditions is the one which is usually taken and with which the physician is mainly concerned Indeed clinical evidence shows that a transient elevation in the blood pressure due to emotional influences may have great prognostic significance Von Monakow[149] in 1920 and Stieglitz[150] in 1930 on the basis of their clinical experience asserted that a transient rise in blood pressure due to emotional factors may indicate a predisposition to the later development of hypertension Palmer[151] and others[35, 154] after long follow up studies have shown that a transient elevation of the systolic and diastolic pressures even in young people greatly increases the possibility of persistent hypertension in later life Master[152] re-examined 50 patients forty years of age and over who had had a single blood pressure reading which was at the upper limit of normal (140 156/80-94) during their stay in the hospital one to seven years previously On the re-examination 38 of the 50 were found to have hypertension and at least 25 per cent had a diastolic pressure of over 100 He therefore concluded that even a single borderline reading may be of some prognostic significance In a recent study by Levy, et al[154] the medical records of

22,741 officers of the United States Army were analyzed. The observation period extended from one to more than twenty-five years. They found that sustained hypertension occurred more frequently in those who had had previous transient hypertension at all ages than in those who never showed an elevation of blood pressure. In both groups the rate increased with advancing years. These studies also indicate that an increase in the casual blood pressure may be of prognostic importance.

Finally, it is clear that the "casual blood pressure" is that level of blood pressure to which the individual is subjected during the manifold emotional and mental strains and tensions of his everyday life. From a practical point of view this level may be of more prognostic significance and of more importance to a patient than the "basal blood pressure," which is probably attained only occasionally, if at all, during the day. For all these reasons it is of paramount importance to establish the normal range of the casual blood pressure fluctuations as obtained in everyday clinical practice.

SOFT TISSUE AND VASCULAR FACTORS

The degree to which soft tissue and vascular factors may influence the level of the blood pressure reading as obtained with the pneumatic cuff is of practical and clinical importance. Unfortunately, not much work has been done in this field and the problem is far from being solved.

It has hitherto been generally believed that the soft parts of the arm have a negligible influence on the blood pressure readings. Hensen[6] and Janeway[157] each reported a case with extreme muscular atrophy in one arm and with well-developed muscles in the other. In these cases the blood pressure was identical in both arms. Janeway also pointed out that low systolic readings may be obtained in individuals with obese or muscular arms. Hence the conclusion was reached that the soft parts do not influence the blood pressure reading. More recent work, however, questions the validity of this conclusion. The discrepancy between the direct arterial pressure and the indirect blood pressure as measured with the pneumatic cuff has often been observed. The results have been somewhat conflicting. Most observers reported the direct pressure reading to be lower than the indirect,[158–16] while others[163–16] found in the majority of cases the converse to be true. None of these investigators attempted to explain the discrepancy by the size of the arm. In 1934 Hamilton[166] and his associates introduced an improved optical manometer which was particularly well adapted for recording human intra-arterial pressure. Subsequently, in studies of children, Hamilton[167, 168] and his associates compared the direct and indirect blood pressure readings. They demonstrated that the relationship between the *size of the arm* and the *width of the cuff* greatly influenced the accuracy of the indirect blood pressure readings. In general, they believed that

the size of the cuff should be varied directly with the circumference and length of the arm in children. They suggested a 2.5 cm. cuff for newborn infants, a 5 cm. cuff for small children and a 9 cm. cuff for older and more developed children. A 13 cm. cuff is considered satisfactory for adults. If the person is unusually obese, however, a wider cuff must be used and even then it will be difficult to obtain an accurate reading. Ragan and Bordley[169] simultaneously measured the blood pressure by the intra-arterial method of Hamilton and by an auscultatory method similar to that used in routine clinical blood pressure determinations. They also found that the difference in the pressure obtained by these two methods was affected by *the size of the arm. Incorrect readings were obtained* particularly in subjects with unusually large or unusually small arms. When the arm was large and the standard 13 cm. cuff was used, they found that the systolic and diastolic pressure was likely to be too high. The error in either direction may exceed 30 mm. mercury. In some obese subjects the use of a wide 20 cm. blood pressure cuff resulted in more accurate auscultatory *measurement of both the systolic and the diastolic pressure. In most patients, however, the wider cuff yielded* readings which were too low.

In order to obtain an accurate measurement of the pressure in the femoral artery, a cuff at least 15.5 cm. wide must be used; the ordinary 13 cm. cuff gives false readings.[170] Some authors have shown that the pressure in the femoral artery is higher than that in the brachial in both man[171] and animals.[172]

The American Heart Association *felt that this important problem* must be clarified and specific instructions for taking the blood pressure in relation to the size of the limb should be given.

In June 1951 the Scientific Council of the American Heart Association* discussed the accuracy of the indirect auscultatory blood pressure measurement in comparison with that of direct blood pressure measurement by means of calibrated intra-arterial manometers. It found that the auscultatory *systolic pressure in the brachial artery is on the average 3–4 mm.* mercury too low and that it varies ± 8 mm. mercury. It found too that the auscultatory diastolic pressure taken at the 4th phase (muffling of the sounds) is on the average 8 mm. mercury too high. The Council therefore concluded that the indirect auscultatory method of measuring systolic and diastolic pressures may be expected to result in a mean error of ± 8 mm. mercury.

The Council for High Blood Pressure Research of the Scientific Council of the American Heart Association through the Committee to Revise Standardization of High Blood Pressure Readings,* recommends that in general the blood pressure cuff must be 20 per cent wider than the

* From "Recommendations for Human Blood Pressure Determinations by Sphygmomanometers," by James Bordley III, M.D., Charles A. R. Connor, M.D., W. F. Hamilton, M.D., William J. Kerr, M.D. and Carl J. Wiggers, M.D. Circulation 4: 503, 1951.

diameter of the extremity to which it is applied It suggests that a 12 cm cuff be used on the arms of adults For children under the age of nine the Council advised that a cuff 8–9 cm in width be used for children under four years of age it suggests a 5–6 cm cuff and for infants under one year of age a cuff of 2 5 cm or less

The Council believes that the systolic pressure in the thigh is from 10–40 mm mercury higher than in the arm but that the diastolic pressure is the same in both It recommends that an 18 cm cuff be used on the thighs of adults They also believe that a variation in the diastolic pressure in the upper and lower extremities of a *normal* person is due to the use of an insufficiently wide thigh cuff and is a test of the adequacy of the cuff employed

The inflatable bag should be at least long enough to cover half the circumference of the limb care should be taken however that the bag is placed over the artery that is to be compressed Since the danger of the improper application of the bag must be obviated it evidently is preferable that the bag be long enough to encircle the limb or to cover the greater part of it

The results of these recent extensive investigations prove that the size of the limb is an important factor in the production of minor depressions and elevations of the blood pressure when the standard cuff is used The size of the limb therefore must also be considered when an evaluation is made of the diagnostic and prognostic significance of these minor variations in the blood pressure Thus when the standard cuff is used on an obese person an elevation of the blood pressure may be due entirely to soft tissue factors and may not be evidence of an abnormal condition When it is used on a thin armed person on the contrary the blood pressure reading may be too low This soft tissue factor therefore should be considered and assessed in each individual case

The relationship of the *vascular factor* to the blood pressure reading—the quality and tonus of the arterial wall—has been a matter of interest and concern for a number of years There appears to be general agreement that the *quality of the arterial wall* has a negligible influence on the blood pressure reading Von Basch[60] crudely measured the amount of pressure necessary to obliterate the empty radial artery and found it to be 1 mm mercury for normal vessels and not much above 5 mm mercury for sclerotic vessels Janeway [74] using a wide armlet studied many cases with marked thickening or calcification of the larger arteries also found that the error from this source was negligible Martin [1 3] in a few experiments on the carotid arteries of man horse and dog found that a pressure of 2 mm mercury was sufficient to collapse the normal arterial wall and that a pressure of only 7 mm was required to collapse markedly sclerotic vessels In more extensive experiments on segments of surviving arterial wall in animals and man Janeway and Park [174] and MacWilliam and Kesson[175] have shown that the lumen of large ar

teries such as the brachial may *be obliterated by the pressure of only* a few mm mercury Atheroma and calcification even of considerable degree are without appreciable effect on the compressibility of the artery and, hence on the blood pressure

There is general agreement however that the state of contraction or *tonicity* of the underlying segment of arterial wall may have a more important effect on the blood pressure than calcification of the arteries Contraction of the muscular coat of the arterial wall may cause an increase in the blood pressure level Russell[176] was one of the first to recognize the effect of hypertonus of the underlying arterial wall on the blood pressure However he exaggerated its importance He even thought *that arterial hypertonus* rather than arterial hypertension is measured when the obliteration method is used

Experimental work was done on blood vessels in animals and man to evaluate the arterial factor MacWilliam and Kesson[175] found that spasm of the arteries of sheep and cattle could greatly increase their resistance to compression Only a few mm mercury were necessary to compress the relaxed carotid artery of the sheep and ox The resistance of contracted arteries to compression however varied directly with the amount of contraction present Thus a pressure of 35 mm was required to obliterate the carotid of the sheep contracted at body temperature and a pressure of 64 mm was required to obliterate the carotid of the ox when the temperature was lower a pressure of 186 mm mercury was at times required to collapse the latter From a study of human beings MacWilliam and Kesson[175] concluded that abnormal resistance of the arterial wall due to contraction of the muscular coat can play an important rôle in elevating the blood pressure Janeway and Park [174] on the contrary as a result of experiments on surviving ox arteries and of a study of human arteries after amputation and postmortem felt that hypertonic contraction of the brachial artery sufficient to cause an error of more than 30 mm mercury was improbable

Although the results of the animal experiments cannot be applied directly to man it seems evident that spasm of the segment of the arterial wall underlying the pneumatic cuff may be a significant factor in some cases in causing an increase of the blood pressure

According to MacWilliam and Kesson [175] continued or repeated compression as well as massage of the arterial wall segment may overcome an existing spasm To eliminate it the blood pressure should be taken several times in rapid succession on the same arm This procedure may not only overcome the underlying spasm of the arterial wall but may also reduce the psychic stimulation caused by the examination A comparison of the blood pressure in both arms should be made after such a procedure in an endeavor to determine the degree of elevation of the blood pressure caused by the spasm

WEIGHT

The blood pressure tends to increase with increasing weight. This has been shown to be true by many investigators and has been generally accepted. Symonds in comparing the blood pressure of the heaviest and lightest groups of accepted insurance risks of all ages found that there was an average increase of 10 mm. in the systolic pressure in the former and a proportional increase in the diastolic pressure. Huber[17] after examining 1,352 healthy men found that 40 per cent of those who were more than 10 per cent underweight had a subnormal blood pressure while 18 per cent of those who were overweight had a high blood pressure. Hartman and Ghrist correlating the blood pressure to the weight of 2,042 registrants in the Mayo Clinic fifteen years of age and over found a step-like increase in systolic blood pressure with increase in body

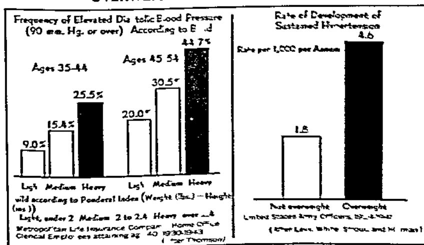


Fig. 2

weight. Short and Johnson after studying 516 individuals who applied for periodic health examination also found that the average blood pressure was consistently higher in the overweight group. Faber obtained similar findings in 1000 healthy individuals between the ages of twenty to twenty-five years. Hence we may well conclude that in some way increasing weight causes increasing blood pressure. That pathologic hypertension is very much more frequent among the overweight than in those of normal weight or in those who are underweight is also a well established fact. Overweight has been shown to be a very definite factor in the causation of hypertension (Fig. 2).

The mechanism whereby increasing weight causes a rise in the blood pressure is not clear Ragan and Bordley [169] using the standard 13 cm wide cuff have shown that the soft tissue factor in very obese arms may be important in producing an increase of the blood pressure reading However this would apply only in a small number of cases Moschcowitz[187] has suggested that the rise in pressure is a compensatory effect to meet the extra burden placed on the heart which does not always keep pace in size and weight with the growth of the body He felt that this could explain the reduction in blood pressure after weight loss and the tendency to low blood pressure in thin individuals

Conversely reduction in weight produces a lowering of the blood pressure This holds true not only for hypertensives but also for normal individuals Thus in a study of 1000 obese patients Preble[188] demonstrated that a reduction of 10 pounds in weight caused an average drop of 18 points in the systolic pressure and 10 points in the diastolic pressure Similar results were reported by Terry [184] Bauman [186] Moschcowitz [187] and others

RACE AND GEOGRAPHIC LOCATION

The blood pressure level seems to vary with race and geographic location People in tropical and subtropical climates appear to have lower blood pressures and the incidence of hypertension among them is low Thus certain groups of Chinese Filipinos Puerto Ricans East Africans Indians Arabs and aborigine Australians seem to have a lower blood pressure and less hypertension than do the North American or other Western peoples [189–198] Whether this difference is racial or climatic in origin or is mostly due to a slower tempo of life in the warmer climates it is difficult to say American negroes however have higher blood pressures than do white males after the age of twenty Alvarez and Stanley [199] in a study of blood pressure readings in 6000 prisoners found that the blood pressure rose more rapidly with age in negroes than in whites In a comparative study of 8000 apparently healthy white individuals and 6000 apparently healthy negroes Adams [90] in New Orleans found that the blood pressures of the colored were higher than those of the whites After the age of forty also the pressure increased more rapidly in the negroes than in the whites Weiss and Prusmack [201] found a reportedly greater incidence of hypertension in the negro than in the white race Among 1000 negro male factory workers in the Cincinnati area 249 had hypertension whereas among 1000 male white workers of approximately the same age in the same community only 91 had hypertension These findings are in distinct contrast to those reported by Donnison [99] he found that the blood pressure among African negroes is about the same as that among whites up to the fourth decade after which it is distinctly lower Thus African negroes appear to have

a lower blood pressure than do those of their race who live in America This at once suggests that psychogenic factors probably play an important rôle in the production of the higher blood pressures among the American negroes

China appears to provide an environment favoring lower blood pressures Cadbury[303] taking the blood pressure of 774 young Cantonese students found that the systolic and diastolic pressures were lower when compared to the pressures of European or American youths of similar age weight and height Tung[14] studied the blood pressures of 58 Americans before and after they resided in China He found that the average systolic pressure decreased 9 mm mercury and that the diastolic decreased 11 mm during their residence in China Forster[70] also found that Occidentals living in China have a lower blood pressure than Americans the average for the foreigners being the same as for the local Chinese Conversely Krakower[206] has stated that the blood pressure of Chinese after long residence in Canada approximates that of other Canadian residents and that essential hypertension is common among them This tends to indicate that the differences in pressure may be related to the physical environment The slower tempo of life and the decreased amount of psychic stress in the eastern countries undoubtedly have an important effect on the blood pressure

MEALS INGESTION OF LIQUIDS DIET STARVATION EXERCISE ALTITUDE ETC

There are many other factors which affect the blood pressure but these are of little clinical importance and as a rule exert a negligible influence on it Many of these factors were illustrated by various observers at the beginning of clinical sphygmomanometry However their technique was inaccurate as compared with present day standards (they employed the 5 cm armlet with the Riva Rocci sphygmomanometer the von Basch and Gartner sphygmomanometer) but the trend of their results is still correct As was previously stated a number of studies have shown that the blood pressure falls during the early hours of sleep During the day the pressure has been found to increase slowly reaching a maximum in the early evening as a rule at 6– P. M. and then decreasing somewhat until bedtime[4, 9, 137, 9, 209] Some of this diurnal rise has been attributed to the digestion of food[38, 4, 39, 61, 6, 87, 89–91] since this causes a slight but definite rise in the systolic pressure and a lesser rise in the diastolic Ingestion of liquids[7, 13, 314] can also increase the blood pressure

Diet also may exert a minor effect on the blood pressure Thus Saile[6] compared the pressure of vegetarian and meat eating monks and found that the latter had a consistently higher blood pressure in each age group Starvation can lower the blood pressure as was strikingly demon

strated during and immediately after the two World Wars by observers in Germany.[216, 217] It is of course a factor of minor importance in this land of plenty.

Muscular exercise[1, 3, 11, 18] may account for some of the increase in the pressure during the day. With light exercise the diastolic pressure may remain at a normal level while the systolic rises several millimeters. Strenuous exercise, however, causes a marked increase in the systolic pressure and a lesser increase in the diastolic pressure both during and after the period of exercise. All these factors account to some degree for the diurnal variation in the blood pressure.

Position usually has little effect on the blood pressure. The Committee on Standardization of Blood Pressure feels that there is no significant difference in the blood pressure taken in the lying or sitting position. The standing and recumbent systolic blood pressures also differ very little as a rule. However, the diastolic pressure is usually higher in the standing than in the recumbent position. This difference may amount to 8 mm. mercury or more in some cases.[18]

Pregnancy is considered a factor which may influence the level of the blood pressure but the changes cannot be foreseen. Faught[219] in a study of 100 normal pregnant women found marked variations below or above the normal limits but the average remained within normal limits. Cornell[220] in 1000 pregnant women found 18 per cent to have a systolic pressure of more than 140 mm. mercury; in general he found a slight drop during the third and fourth months of pregnancy and a gradual increase from the seventh month until the time of delivery.

An *inequality of the blood pressure in both arms* was at one time considered to be a sign of an aneurysm of the ascending aorta. It has been shown, however, that many normal people may have a different pressure in each arm. Korn and Cuinand[221] in 1000 healthy people (731 males and 269 females) ranging in age from sixteen to forty-nine years found this condition present in 38 per cent of the cases. In 21 per cent the difference was more than 10 mm. mercury. Seventy-five per cent had a higher pressure in the right arm than in the left. The exact mechanism of this disparity in the brachial pressure is not known.

Changes in *altitude* have very little effect on the blood pressure and what effect occurs is a variable one. Clough[222] and others[223, 224] found that it was impossible, as a rule, to forecast the influence which a change in altitude would have on the blood pressure. In some cases a slight rise occurred, in some a slight fall, while in many the findings were unchanged.

SUMMARY

Many factors affect the blood pressure reading. They should be considered in each individual case in evaluating variations of the blood pressure from the normal.

The most important factors are

(1) *Age and Sex* —Blood pressure normally increases with age It is lower in females under 40 years of age compared with males and is higher in females after the age of 40 Age and sex therefore must be considered when the normal range of blood pressure is defined

(2) *Emotion* —Emotional disturbance especially fear cause transient blood pressure elevation This may have some prognostic significance indicating an increased tendency toward the development of a sustained hypertension later in life The variability of the blood pressure caused by the emotional factor has been largely eliminated by recording basal blood pressures However this is not practical in clinical medicine where the casual blood pressure reading is the one utilized The latter is undoubtedly a closer approximation to the level of the blood pressure with which the patient lives in his everyday life It is important therefore to endeavor to establish the normal range of the casual blood pressure

Less important factors are

(3) *Soft Tissue and Vascular Factors* —With the standard 15 cm cuff an excess of soft tissue such as occurs in a very obese person may cause an increase in the blood pressure reading, a thin arm may cause the reading to be too low Thickening of the arterial wall and arteriosclerosis do not affect the blood pressure reading Spastic contraction of the muscular coat of the segment of the arterial wall underlying the pneumatic cuff may cause an elevation in the blood pressure This may be eliminated by massage or repeated compression with the cuff

(4) *Obesity* —The blood pressure increases with increased weight and is lowered by weight reduction

(5) *Race Meals Exercise Position Altitude Pregnancy and Starvation* —These are minor factors which do not exert an appreciable effect on the blood pressure

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Chapter IV

THE NEED FOR INCREASING THE RANGE AND LIMITS OF NORMAL BLOOD PRESSURE—NEW LIMITS OF HYPERTENSION

SINCE hypertension and hypertensive heart disease are today considered to be among the commonest types of cardio vascular affections,[7] the correct clinical interpretation of blood pressure readings is of paramount importance. This is assuming an ever increasing importance because many more people now undergo routine health examinations in the physician's office, in industrial plants, in public health studies, in the military establishments and in life insurance companies. The need for the proper interpretation of blood pressure values is growing more urgent also because of the increase in the number of older people in the United States—the increase resulting from the lengthening of the span of life during the past several decades.

In spite of the large amount of data that has accumulated, a wide divergence of opinion still exists concerning the normal range of the arterial blood pressure. During the past thirty years an increasing number of authorities in the field has accepted 140–150 mm. mercury as the upper limit of the normal systolic pressure, and 90–95 mm. as the upper limit of the normal diastolic pressure, irrespective of age and sex. These constitute the present commonly accepted limits and have been established largely through studies made by life insurance companies. Their results were based on data which related the average blood pressure readings to group mortality rates. Their tables are still cited in most textbooks as the basis of normal blood pressure levels.

Notwithstanding the fact that insurance companies have contributed much to medical progress through their accumulation of vast amounts of material and of experience in various fields, their conclusions regarding normal blood pressure limits cannot be accepted in clinical medicine. The objections to using insurance company mortality statistics as a basis for the establishment of normal blood pressure limits are manifold: insurance companies are concerned only with a highly selected group of accepted risks; they consider the longevity and mortality of large groups and their results cannot properly be applied in clinical practice, which considers individual cases. They examine more males than females, the majority of whom is young—and since hypertension is known to be more serious in youth than in age, and to result in higher mortality in men than in women, the insurance company figures are biased. The

insurance companies disregard also the degree of individual variability of blood pressure, which is a physiologic characteristic and disregard also the increase in the pressure with increasing years. Indeed the insurance companies approach to the problem has in reality been an attempt to define an ideal blood pressure rather than its normal range of variation.

Insurance statisticians seek to determine the particular range of blood pressure within which they can accept risks with profit. Hunter[23] actuary of the New York Life Insurance Company frankly stated that "the purpose of the preparation of these statistics was not to excite public interest or curiosity but for actual use in a great business." Symonds[77] Medical Director of the Mutual Life Insurance Company put the matter rather well. "Probably life insurance and general medicine will never regard blood pressure in the same light. Life insurance sees only persons who are healthy, or *think they are*. General medicine knows that many patients with high pressures (170-200 mm) will live for many years. If a practitioner should see 1000 patients with high blood pressure at age sixty and wager with himself that 974 would survive the year and only 960 survive he would not feel downcast. In fact he would probably point to the record with pride and boast of his ability in prognosis. But life insurance would have to tell him that his mortality was 150 per cent in that group and a medical director who did not make a better guess than that would not hold his position long. General medicine would look complacently at the living but life insurance would ruefully regard the dead for 40 claims would have to be paid instead of the 26 expected." Other insurance authorities have emphasized the point that it was unwise to accept insurance company limits too literally and that a less dogmatic point of view was indicated. MacKenzie[86] of the Prudential Life Insurance Company states that "The systolic may vary to such an extent under emotion, nervousness, muscular strain, etc., that in our judgment we may usually disregard it when the diastolic is normal for the age and the applicant normal in other particulars." Furthermore according to MacKenzie blood pressure readings decidedly beyond the acceptable limits "are constantly reported but are not usually considered cause for immediate action in otherwise insurable risks." The figures which MacKenzie[86] gives should be used "as guides and not arbitrary limits."

It seems obvious from the foregoing that the blood pressure limits set by the insurance companies are too rigid but before we leave this topic we must mention the limits set by Robinson and Brucer[93] whose study is widely quoted because *these are even less liberal than those set by life insurance companies*. They maintained that the upper limit of the normal blood pressure was 120/80 mm mercury for all ages and for both sexes. Treloar[96] believed that the statistical methods employed by Robinson and Brucer were unsound. His main criticism was that

their conclusions were based on a biased selection of cases and did not represent a fair random sample Furthermore all cases with a blood pressure greater than 140/90 mm mercury had been eliminated from their study without proper justification For these and other statistical reasons the validity of their conclusions is highly questionable

Since as has been shown the present day blood pressure limits, set by the insurance companies are unsound and since the same fixed limits for all ages and both sexes cannot be accepted a more liberal approach to the blood pressure problem, and a correct clinical interpretation of blood pressure measurements are necessary From time to time various reports have stressed the need for liberalizing our concepts of the limits of the normal blood pressure The results of these investigations fall into 3 large groups

1 Those indicating that the blood pressure increases significantly with age

2 Those demonstrating the high incidence of so called hypertension in the normal population

3 Those showing the benign course of many hypertensives

1 BLOOD PRESSURE INCREASES SIGNIFICANTLY WITH AGE

Physicians have long known that the systolic blood pressure increases with age The dictum that the normal systolic blood pressure expressed in mm mercury equals 100 plus the patient s age expressed in years was commonly accepted in the early period of clinical sphygmomanometry Other formulas [7, 8] based on the age of the patient were later introduced Peters [2, 7] in 1925 stated that the normal systolic pressure ranged from 90 to 130 mm plus one half the patient s age in years—thus for a man of forty its normal range was between 110–150 mm Alvarez and Stanley [199] on the contrary stated that a pressure of 115 mm is just as normal and a pressure of 140 is just as abnormal in an old man as in a young man According to them the blood pressure varied little with age—and this opinion has been generally accepted Within the last twenty years or so therefore the upper limit of the normal systolic pressure has been lowered so that today 140–150 mm mercury systolic and 90–95 mm mercury diastolic are generally regarded as uppermost normal levels irrespective of age

Observations reported by numerous investigators over the course of many years however disprove the concept that the blood pressure is normally altered little by age I otain in his extensive experience with over 11 000 blood pressure readings found that the systolic pressure normally did increase with age In 1909 Tavaststjarna [7, 9] in Finland reported the normal pressure ranges which he had found in 487 people

from seven to ninety years of age The following table has been adapted from his results

TABLE V —BLOOD PRESSURE IN 175 INDIVIDUALS—TAVASTSTJARNA (1909 ADAPTED FROM KYLIN)

Age	*Systolic Pressure* Range	Average	Number of Cases
16	89 142	111	28
18	95–132	112	12
22	92–142	116	58
25	95–142	122	20
26–30	110–142	121	21
31–40	99 170	121	21
41–45	102–180	134	5
61– 0	130–175	155	3
71–80	142 248	199	7

Although the number of cases in each age group is relatively small the trend to an increase in the blood pressure with age is apparent

Similar results were obtained in studies on older age groups by Wildt[230] in 1912 Wikner[231] in 1916 Bowes[232] in 1917 and Richter[233] in 1923 Table VI taken from Richter is representative of their findings All the patients were ambulatory Those with nephritis and heart disease had been excluded

TABLE VI NORMAL BLOOD PRESSURE IN OLDER AGE GROUPS—RICHTER (1923)

Age	Average Systolic Pressure	Number of Cases
60–64	138	10
65–69	150	29
70–74	156	35
75 79	155	52
80–84	157	24
85 89	161	15

It must be stressed that averages are given in this table *These do not* take into account the normal variation of the blood pressure and hence do not represent the limits of the normal The upper limit of the normal blood pressure is necessarily higher than the average pressure This is important and should be borne in mind when subsequent reports are evaluated

In 1928 a very important study was published by Saller [34] who recorded the blood pressure in 4 128 people in an out patient clinic in Kiel He excluded all patients with organic heart disease kidney disease anemia diabetes fever and endocrinologic disturbances His results are summarized in Table VII

TABLE VII —BLOOD PRESSURE RANGE IN 4 128 PEOPLE—SALLER (19 9)

	Range of Systolic Pressure	
Age	*Men*	*Women*
21–35	98–144	99–139
36–47		100–155
48–53	96–154	100–190
54–59	97–159	104–196
60–67	93–173	102–216
68–8[illegible]	86–196	112–222

The salient finding of Saller was a gradual increase in blood pressure after the age of forty seven the rise being higher in the females than in the males The wide range of the systolic pressure found by Saller is also of great importance It is obvious that the use of the *average* blood pressure as a criterion has very little value when such a wide range exists Saller did not claim that all blood pressures lying within these limits were normal He concluded however that if the blood pressure is within these limits one cannot be sure that it will have any influence upon the length of life of the individual He suggested that the increase of blood pressure with old age should be considered a part of the ageing process and that it may be likened to other changes which occur with age such as those found in the hair the teeth the eyes and the libido

In an excellent critical review in 1936 Bordley and Eichna[23] presented a table arranged from material collected by Weatherby which demonstrates nicely the rise in blood pressure with age and the higher blood pressure levels in females in the older age groups Cases with nephritis and aortic insufficiency had been excluded

TABLE VIII —AVERAGE BLOOD PRESSURE (MM MERCURY)—WEATHERBY (1935)

	Men ([illegible])		*Women (3 258)*	
Age	*Systolic*	*Diastolic*	*Systolic*	*Diastolic*
15–19	116	73	118	75
20–29	120	77	120	77
30–39	123	80	126	80
40–49	12[illegible]	82	139	86
50–59	137	85	153	90
60–69	147	89	164	93
70 & over	158	89	174	95

Weatherby found that a rise in diastolic pressure also occurred with increasing age.

Lewis [36] in 1938 studied the blood pressure of 100 men, 20 in each decade from forty to eighty-nine years and found a definite rise in the systolic pressure with increasing age. The average diastolic pressure, however, did not change much. In 1941 Miller [37] reported on blood pressure studies on 853 men and 128 women fifty years of age and over. He also found a definite rise in the average systolic pressure with age, the pressure being higher in women than in men of all age groups. The diastolic pressure, however, varied only slightly. In 1946 Russek [38] and his associates reported on the blood pressure levels of 5,331 men between forty and sixty-five years of age. Their results were as follows:

TABLE IX.—BLOOD PRESSURE IN 5,331 MEN—RUSSEK (1946)

Age	Average Blood Pressure (mm. Mercury) Systolic	Diastolic	Number of Cases
40–49	135	86	1640
50–59	141	87	1414
60–69	151	88	1124
70–79	157	89	772
80–95	162	88	381

Russek concluded therefrom that the average systolic pressure increases significantly with age, whereas the average diastolic pressure shows little variation after the sixth decade. On the basis of these and other studies Russek [39–41] suggested that the formula "100 plus the age" may reflect fairly accurately the tendency of the normal systolic blood pressure to increase with age.

Mary Gover [42] in 1948 reported the blood pressure measurements in 9,776 white persons who lived in rural communities. The examinations had been made under the supervision of the Farm Security Administration in 1940. Although this was a selected group of individuals, her findings are of interest.

TABLE X.—BLOOD PRESSURE IN 9,776 RURAL INDIVIDUALS—GOVER (1948)

	Average Pressure (mm. Mercury)			
	Males		Females	
Age	Systolic	Diastolic	Systolic	Diastolic
15–24	126	75	12[illegible]	7[illegible]
25–34	129	[illegible]8	130	80
35–44	133	82	140	85
45–54	142	85	152	88
55 & over	158	91	169	92

Thus in addition to the rise in systolic pressure Gover found that the diastolic pressure also increased with age The increase in the pressure was greater in women after the age of forty

All these findings present a potent argument against the thesis that age does not significantly affect the blood pressure It is evident there fore that the physiologic effects of age and sex on the blood pressure must be taken into account when new normal blood pressure limits are determined

2 HIGH INCIDENCE OF SO CALLED HYPERTENSION IN THE NORMAL POPULATION

As a corollary to the fact that the blood pressure increases significantly with age one would expect to find a high incidence of hypertension in the normal adult population Indeed this has been evident to many ob servers in the last thirty to forty years as shall be shown directly Since the normal increase in the blood pressure occurs at a much more rapid rate after the age of forty the incidence of so called hypertension in the normal population over forty should especially be striking and should increase with increasing age That this is so has been shown by many studies on groups under and over forty years of age

Barach and Marks[243] in 1914 were among the first to point out that a significant number of young healthy men (below forty) had an increased blood pressure They examined 747 male university students who presumably were in good health Four hundred and two (75 per cent) of the cases were between seventeen and twenty one years of age only 2 being over thirty one They divided the group in 2 series only for the diastolic readings They employed the fifth phase in the first group and the fourth phase in the second group for their blood pressure readings They found that 24 per cent of 656 of these students had a systolic pressure of over 140 mm mercury and that 9 4 per cent had a systolic pressure of over 150 mm Thirteen per cent of the second group (312 cases) had a diastolic pressure of over 100 mm mercury Lee[44] examined 662 Harvard freshmen whose average age was eighteen years Twelve per cent of these young men had a systolic pressure of over 140 mm mercury Alvarez[24] found that 22 per cent of a large group of healthy college fresh men (sixteen to forty years of age) had a systolic blood pressure of over 140 mm mercury Diehl and Sutherland[46] obtained the same results in 11 5 per cent of a similar group The great majority of these students was under thirty years of age (Table XI) Durig[47] in Germany Walko[48] in Czechoslovakia and Moisset de Espanes[49] in Argentina also reported a large number of young people (under thirty years of age) with a systolic pressure of over 140 mm mercury

The incidence of elevated arterial blood pressure according to the old accepted limits in the healthy young adult population is thus proven

TABLE XI.—PER CENT OF HEALTHY YOUNG MALES (UNDER 40) WITH SYSTOLIC PRESSURE OVER 140 MM. MERCURY

Author	Per Cent with Systolic over 140	Total Number Examined
Barach & Marks (1914)	24 per cent	656
Lee (1915)	12 per cent	662
Alvarez (1923)	22 per cent	6000
Diehl & Sutherland (1925)	11.5 per cent	5122

to be quite high perhaps therefore the limits of normal that are commonly accepted are too low. If they are not an unduly large number of the young adult population will be considered to be hypertensive. The need for a new approach to the problem is therefore again evident.

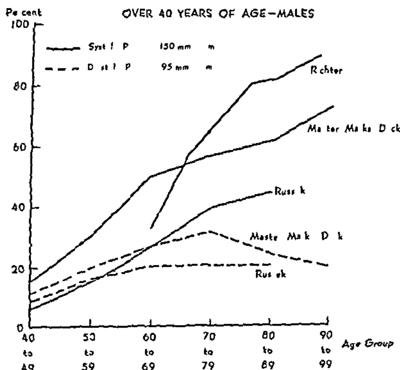


FIG. 23.—Percentage of cases with systolic pressure of 150 mm. mercury or more and diastolic pressure of 95 mm. mercury and over given by different authors.

In the groups who are over forty years of age the high proportion of hypertensives is even more striking and significant if the present day criteria (150/90-95 mm. mercury) are employed. A number of impressive studies has been published on this subject, a few of the more important

ones are summarized in Figure 23 In 1912 Wildt [30] found tha per cent of people over sixty years of age had a systolic hy Similar findings were reported by Weitz [0] and by Richter [33] studies done on an unselected large group of patients Gager [1] in 19.. Blackford Bowers and Baker in 1930 and Braasch Walters and Hammer [253] in 1940 found a steadily increasing percentage of high blood pressure with increasing years and a conspicuous rise in its frequency in the fifth decade Furthermore, after the age of forty the incidence of hypertension was found to be greater in women than in men This is in accordance with the finding that the normal blood pressure increases with the years, and is greater in females after the fifth decade than in males

In 1943 Master Marks and Dack[254] analyzed the blood pressure measurements found in 14 849 people (8 483 men and 6 366 women) These were industrial workers residents in homes for the aged and non selected patients in a general hospital The following table, taken from their report summarizes the incidence of hypertension found according to the various definitions of the normal

TABLE XII --INCIDENCE OF HYPERTENSION IN NORMAL POPULATION— MASTER MARKS AND DACK (1943)

Degree of Hypertension in mm mercury	Age Group Years	Percentage Male	Percentage Female
140/90 or over	40 and over	50	60
	50	51	72
	60	70	70
	70	77	82
150/90 or over	40	41	51
	50	50	62
	60	60	70
	70	66	74
150/100 or over	40	32	44
	50	43	56
	60	55	66
	70	62	70

A study of their results reveals that the incidence of hypertension rises in each decade until the age of eighty whatever the accepted normal limits may be The percentage is always higher in women Thus using the commonly accepted limits they found that almost one half of the people who are forty years of age and over has hypertension High blood pressure was present in the majority of men who were sixty and over and in women who were fifty years or older

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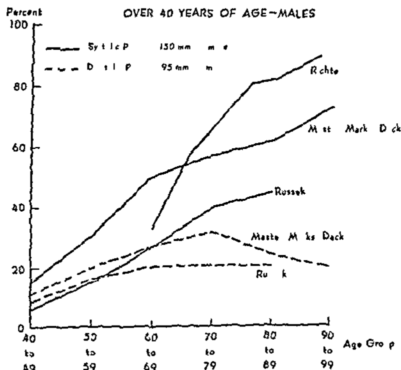


FIG. 23.—Percentage of cases with systolic pressure of 150 mm. mercury or more and diastolic pressure of 95 mm. mercury and over given by different authors.

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sure limits must be liberalized Indeed so called hypertension is the rule rather than the exception in women over fifty and in men over sixty Master Marks and Dack [54] have stated that the high incidence of systolic pressure in people over the age of fifty should not be a cause for alarm A slight or perhaps even a moderate degree of hypertension in older age groups should not be considered abnormal, if the commonly accepted criteria of normal blood pressure limits are used

3 BENIGN COURSE OF MANY ' HYPERTENSIVES

Many physicians have seen people with blood pressure readings above the commonly accepted limits who live their normal life spans without complications related to their blood pressure—their so called hypertension runs a benign uncomplicated course for long periods of time Several reports have appeared which confirm this finding In 1926 Weitz [61] in a three to fourteen year follow up study of 100 hypertensives, the great majority of whom had a systolic pressure of over 200 mm mercury concluded that the course of hypertension is often relatively favorable In 51 of the cases the blood pressure remained unchanged or showed a tendency to fall over a period of from three to eleven years Blood and Perera[26] have recently reported on 50 patients who when first seen exhibited asymptomatic and uncomplicated hypertensive vascular disease Their initial pressure repeatedly exceeded 140/90 mm mercury These patients were followed for from ten to twenty seven years the average length of observation being seventeen years The majority showed well established hypertension at the time of the first examination and may have had an elevation of the blood pressure for an indefinite period before it On the basis of their findings, Blood and Perera[262] concluded that high blood pressure may be compatible with many years of survival and well being Similarly, Perera [263] in a survey of 2 147 hypertensive records with a detailed study and observation of a group of 250 patients, found that long survival (more than twenty years) often with comparative well being is not a rarity He emphasized the fact that the average life expectancy in these cases is undoubtedly longer than is generally assumed A similar study by Ranges [64] of 241 cases of hypertension also demonstrated that its course was frequently benign Burgess [65] observed 100 patients with blood pressures of 180/100 mm mercury or more for at least eight years He concluded that the prognosis in even severe hypertension was usually fair though the condition had been present for eight years or more provided that it was not associated with well established cardiac or renal disease Such patients may live to within three or four years of the average life expectancy

By far the most extensive and comprehensive follow up study was done by Bechgaard [266] He studied 1 038 clinic patients (325 men 713 women),

who, at the first examination had a blood pressure of 160/100 mm mercury, or a systolic pressure of 180 mm or more A second examination of 1 002 of these patients was made four to eleven years later Bechgaard compared the mortality of this group with the expected mortality in the Danish population in similar age groups As was to be expected he found that the mortality ratio rose directly with the height of the blood pressure However the increase of this ratio was marked for those with a systolic pressure only exceeding 200 mm mercury in men and above 220 mm mercury in women As regards the diastolic pressure again

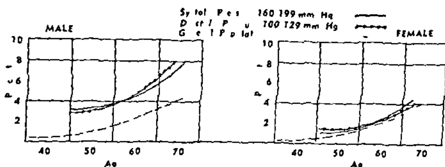


Fig 24 —Mortality rate of patients with systolic pressure of 160 to 199 mm mercury and diastolic pressure of 100 to 129 mm mercury –compared to the mortality rate of the general Danish population (modified from Bechgaard)

a distinct rise in the mortality ratio was observed among males only when this reading exceeded 130 mm mercury (Fig 24) and among the females when it exceeded 129 mm mercury Thus based on the blood pressure readings alone this study shows that the survival record is fair in the great majority of cases with moderate elevation of the blood pressure This is especially true of women in whom the mortality from non complicated hypertension eliminating the most severe degrees is but slightly higher than is that of the general population The findings of Bechgaard are indeed striking The observation that many people with high blood pressure live to a ripe old age suggests that undue significance is frequently attached to the degree of hypertension

The benign course that many so called hypertensives run suggests that many patients are included in this group who might well be classified as being within the normal blood pressure range These people are often enthusiastically but apparently unnecessarily treated for high blood pressure

The handwriting on the wall proclaiming the need for a liberalization of present day normal blood pressure limits has been discernible for some time As a result some physicians have arbitrarily set higher normal limits Thus, in the older age groups Last and Bain[101] used a limit of

160/100 Evans[68] 180/110 Deschamps[69] 180/100 and Perera and Atchley[147] 180/100 mm mercury Others have commented on the difficulty of defining the normal blood pressure limits Dexter[70] states that it is ' impossible to define a truly normal level Gavey[57] has written that there is no normal for old age None of the earlier accepted limits takes into account the important influence of age and sex which must be considered in establishing new limits of normal blood pressure

SUMMARY

1 The present day normal blood pressure limits were established largely as a result of life insurance company studies Conclusions drawn from these studies are not applicable to clinical medicine since they are based on the findings in a selected group and are derived from a statistical analysis of group mortality rather than from a consideration of individual unselected cases

2 Many studies indicate that the blood pressure normally increases significantly with age This rise is more rapid and greater in females than in males after the age of forty

3 There exists a high incidence of so called hypertension in the normal population Using present day limits studies indicate that the majority of women over fifty and of men over sixty is hypertensive

4 Many people with elevated blood pressure may live their normal life spans without complications related to the blood pressure

5 The need for upward revision of the commonly accepted limits of normal blood pressure—140 to 150 mm mercury systolic and 90 to 95 mm mercury diastolic—for each age group and for both sexes is therefore clear

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Chapter V

PRESENTATION OF NEW LIMITS OF NORMAL BLOOD PRESSURE

NUMEROUS studies have hitherto been made on the limits of the normal blood pressure and various results have been obtained. *It is difficult to corroborate the data thus made available especially because each student of the problem has used his own particular technique and has applied it to some particular age group.* The medical literature is replete with the reports of studies made on children, soldiers, students, insurees, prisoners, elderly persons and inmates of old age homes. The curves representing the results thus found cannot be combined since their ends are rarely continuous.

Besides many of the studies have heretofore dealt largely with the average or mean values of the normal blood pressure and obviously the average blood pressure reading gives no indication of the frequency or degree of the normal variation around it. Important though it is, the range of this normal variation has been disregarded because of the difficulty of delimiting it satisfactorily. Yet it is precisely the limits of *the normal blood pressure range which interest the practicing physician* and not the average or mean pressure. It is evident also that one pair of figures for the systolic and diastolic pressure cannot apply to all age groups and to both sexes. When new limits of normal blood pressure are propounded they must make allowance for the effect of sex and increasing years on the blood pressure of the normal population.

Several methods can be employed to determine the normal range of the *blood pressure. The most accurate but least feasible* is to examine each individual in a large representative group of the population repeatedly year after year until his death. The range of variation of the normal blood pressure could thus be discovered as well as the significance of certain particular variations. An alternative method is to collect and tabulate voluminous data on blood pressure levels in the normal population and to endeavor to determine the normal pressure range by statistical studies. *With such a method a fair sampling of the population is* very important. Alvarez[17] has suggested that an ideal way would be to examine every tenth individual passing a certain point on a busy street. Allen and Hines[1] discuss the difficulty of getting a large unselected group of presumably normal persons for blood pressure readings and suggested that *The ideal way would be perhaps to put up booths* in various parts of several towns and cities and there to make a pressure

reading on each of the first 5000 persons to pass by However, this too is not a practicable procedure

The insurance companies examined a very select group of the population in amassing their data and used mortality figures to determine the 'normal' blood pressure levels acceptable to them For these reasons particularly the results of their studies cannot be applied in clinical medicine

In the study to be presented a statistical definition based upon the distribution of the blood pressure readings around the mean was employed [27] Casual blood pressure readings were utilized since the casual reading is most often used by the physician as an aid in the diagnosis and prognosis of disease Allen and Hines[27,16] stress the importance and value of the casual blood pressure because it is the pressure which the patient has during the many hours of the day in which the patient is subject to the wear and tear of work emotion and fatigue As has already been shown transient elevations in the casual readings may have prognostic significance For this reason also it is of paramount importance to endeavor to establish the normal range of fluctuation of the casual blood pressure as obtained in everyday clinical practice and on special medical examination

We believe that the data presented and analyzed in this report define the limits of normal blood pressure for both men and women between the ages of sixteen and sixty five The group studied is large enough to be representative of the general population of the United States The blood pressure readings were accurately taken by trained personnel under conditions which were fairly uniform

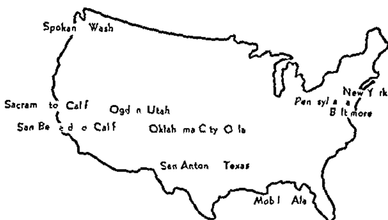
MATERIAL

Through the extensive industrial medical services established during World War II blood pressure readings were taken in large numbers of workers who were in good health These readings obtained from industrial plants in various sections of the country form the basis of the present analysis

The majority of those examined was at work but the readings of those who had applied for employment were included though they may have been rejected Executives clerical workers and manual workers both skilled and unskilled all were examined although no attempt was made to identify specific occupations The records did not show whether the individuals were white or colored but the great majority was white The method of recording the pressure and the general care used in taking it was determined by correspondence Altogether unselected records of about 74 000 persons in 16 industrial plants and Army airfields (civilian personnel only) were collected (Figure 25) This is only about one half of the number of persons who had been examined and whose records

were available to us. The blood pressure readings of the others were not considered by us to have been accurately taken and were therefore not deemed acceptable for our analytical study. All the reports were carefully scrutinized. Where, for example, every reading ended with zero, they were all discarded, since it was assumed that they were not accurate.

Because of the large volume of material, 74,000 accepted readings, random samples were taken so that at least 500 readings on men and



DISTRIBUTION BY AGE AND SEX		
Age	Males	Females
16 24	2 994	3 627
25 34	1 282	1 298
35 44	1 129	1 214
45 54	1 041	1 072
55 64	1 111	766
Total	7 557	7 9 7

Fig. 25. —Geographical distribution and number of all cases employed in this study.

women in each five year age group were collected. In a few instances, however, when the number available was less than 500, all the cases were used. The data thus tabulated cover 15,706 persons (7,722 men and 7,984 women) in eleven industrial plants (Figure 25).* Their ages ranged from sixteen to sixty five years. Those over sixty five years of age were omitted from this study since their number was so small. Samples were taken at the ages of 16, 17, 18 and 19, particularly in males

* Civilian workers in Army airfield at Mobile, Ala.; Oklahoma City, Okla.; San Bernardino, Cal.; Sacramento, Cal.; San Antonio, Tex.; Spokane, Wash.; Ogden, Utah; navy workers in the Brooklyn Navy Yard, N. Y.; Bethlehem Steel Co., Pa.; Consolidated Edison Co., N. Y.; and the Eastern Aircraft Co., Baltimore, Md.

during the period before full growth had been attained in order to determine the variation in the range of the blood pressure during these years

Though the material used had been collected during wartime it was but little distorted, because hypertension and hypotension were relatively unimportant as causes of rejection for military service The men in this study are more representative of the male population however than are the women of the female population The men were married or single approximately in the same proportion as is found in the general population except at the military age The occupational distribution was presumably similar to that of the urban population The women in this study as is characteristic of any group of working women were predominantly single or childless most of them were doing clerical work This type of bias in the female group occurred at practically all ages and was probably most pronounced after the age of forty five It is doubtful however whether this bias seriously affects the value of the results since many married women were employed during the war

The data gathered were analyzed as a whole and examined according to the sex the age the weight and the height of the subjects The mean readings the standard deviations * and the coefficient of variation of the systolic and diastolic measurements were computed directly from the raw data In addition the frequency of hypertension as variously defined was determined according to age and sex

STATISTICAL TECHNIQUE

As is well known most measurable natural characteristics yield a fairly symmetrical normal curve or distribution In analyzing the measurements of such a variable physiologic function as the pressure of the blood however difficulties are encountered because exact figures cannot often be obtained Especially is this true since physicians tend to round out the blood pressure readings they obtain to the nearest even digit—most frequently to zero and eight In the present study as in all records of blood pressure measurements the commonest terminal even digit was zero or eight These terminal digits occurred more often in the diastolic readings than in the systolic The distribution of the blood pressure figures below the average for all ages combined is also somewhat different than it is for those above the average For these various reasons a perfectly smooth distribution curve could not be expected Yet in each age group and sex the frequency distribution of the blood pressure levels did yield a fairly normal curve (Figure 26)

* The standard deviation measures in absolute terms the degree of scatter or dispersion of figures in the distribution The coefficient of variation expresses the standard deviation as a percentage of the mean It is a constant and differs from the standard deviation in that the standard deviation measures degrees of variation in concrete units (e.g. pound inch mm Hg etc) while the coefficient of variation is a relative measure of variation

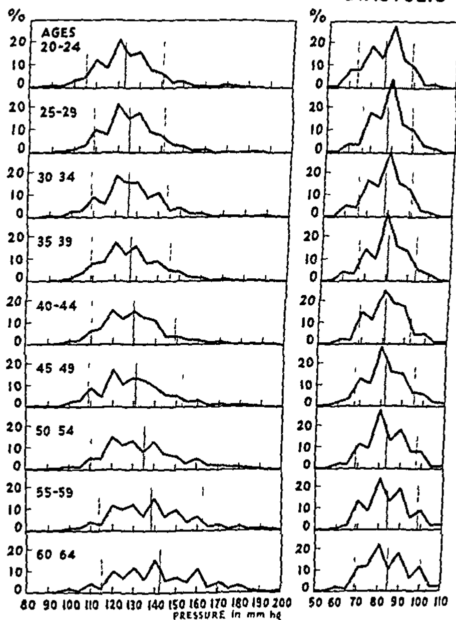


FIG 76A — Frequency distribution curves of entire material (in 5 year age groups) employed to establish new limits of blood pressure for males

FEMALES

SYSTOLIC

%

AGES 20 24

25 29

30 34

35 39

40 44

45 49

50 54

55 59

60 64

80 90 100 110 120 130 140 150 160 170 180 190 200

PRESSURE in mm hg

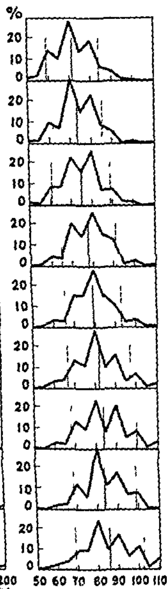


Fig. 26B —Frequency distribution curves of entire material (in 5 year age groups) employed to establish new limits of blood pressure for females

The determination of either the true mean or modal* blood pressure in the various groups studied however was not practicable without laborious curve fitting And since the accuracy of such figures is doubtful, this determination was not attempted

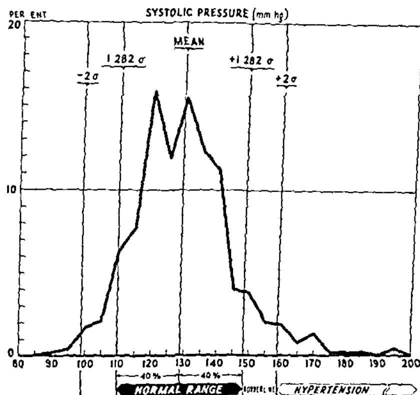


FIG 27

The range of the normal blood pressure is defined statistically, and is based upon the distribution of blood pressure readings around the mean according to age and sex The closer a reading is to the average or mean the greater is the chance of its being normal conversely the further a reading is from the average or mean the greater is the chance of its being abnormal The standard deviation σ is the yardstick commonly used to measure the amount of deviation from the mean In a normal distribution, roughly two thirds (68 27 per cent) of all the observations are found to be within one standard deviation from the mean (mean ± σ) and approximately 95 per cent of all the observations are found to be within

* The mode is the value which occurs most frequently

two times the standard deviation from the mean[275] (mean $\pm 2\,\sigma$) Since there is no definition of what constitutes physiological normality the statistical determination of the normal blood pressure range must of necessity be an arbitrary one Statistically speaking one may assume that any reading within one standard deviation from the mean is within the normal range Indeed the normal range may reasonably be extended to include 80 per cent of all observations—40 per cent on either side of the mean ($\pm$ 1 282 σ) (For computed values see Appendix

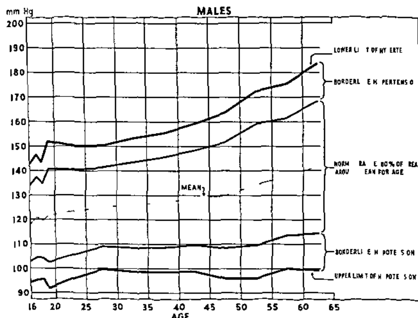


Fig 28

Master Dublin and Marks The Normal Blood Pressure Range and Its Clinical Implications courtesy of J A M A

Tables 1 2 3 4 5 and 6) All blood pressure readings which are found to be beyond two times the standard deviation from the mean are probably abnormal These include 2 5 per cent of all the observations at either extreme The area between the limits of the normal and the probably abnormal constitutes a narrow borderline range

In Figure 27 a magnified typical frequency distribution curve for the systolic pressure in the forty to forty four year age male group is shown The calculated mean the normal the borderline and the abnormal range according to the definitions given are indicated Based upon the

TABLE XIV.—NORMAL RANGE AND LIMITS OF HYPERTENSION

SYSTOLIC

Age	*Normal Range*		*Hypertension Lower Limit*	
	Male	*Female*	*Male*	*Female*
16	105–135	100–130	145	140
17	105–135	100–130	145	140
18	105 135	100–130	145	140
19	105–140	100–130	150	140
20–24	105 140	100–130	150	140
25–29	108 140	102 130	150	140
30–34	110 14	102–135	155	145
35 39	110–145	105 140	160	150
40–44	110–150	105 150	165	165
45–49	110–155	10 155	170	1 5
50–54	115 160	110–165	175	180
55 59	115 165	110–170	180	185
60–64	115 170	115 1 5	190	190

See page 13

TABLE XV.—NORMAL RANGE AND LIMITS OF HYPERTENSION

DIASTOLIC

Age	*Normal Range*		*Hypertension Lower Limit*	
	Male	*Female*	*Male*	*Female*
16	60–86	60–85	90	90
17	60 86	60–85	90	90
18	60 86	60–85	90	90
19	60 88	60–85	95	90
20 24	62 88	60–85	95	90
25 29	65 90	60 86	96	92
30–34	68 92	60–88	98	95
35 39	68 92	65 90	100	98
40 44	70–94	65 92	100	100
45 49	70–96	65 96	104	105
50–54	0 98	0–100	106	108
55 59	70 98	0 100	108	108
60–64	0 100	70–100	110	110

See page 13

Reprinted from the BULLETIN OF THE NEW YORK ACADEMY OF MEDICINE July 1951 Second series vol 27 no 7 pp 460–461 *New and Old Definitions of Normal Blood Pressure: Clinical Significance of the Newly Established Limits*

given statistical definition Figure 28 shows the application of the proposed procedure to the determination of the limits of the systolic pressure among men The wide diagonal area in the middle shows the readings that may be accepted as being within the normal range in successive age groups The heavier lines at the top and the bottom indicate readings according to age that are probably abnormal in the areas between these two are the borderline hypertensive and hypotensive zones This graph is based on the actual computations However since blood pressure readings themselves are not exact some degree of modification of the computed values is necessary This has been carried out in a series of tables which show the range of the normal systolic and diastolic pressure according to sex and age and the limits beyond which readings are probably abnormal[73] (Tables XIV XV)

Blood pressure readings which fall in the normal range should be considered entirely normal Those in the intermediate zone—between this normal range and the lower limit of hypertension —should be considered as probably normal but patients who have such readings should be thoroughly studied before a final diagnosis is established Those readings above the lower limits of hypertension should not *ipso facto* be considered hypertensive though they probably are

RESULTS

1 NORMAL RANGE OF BLOOD PRESSURE

The frequency distribution curves of the systolic and diastolic pressure for each age group and in both sexes are shown in Figure 26 The curves tend to be somewhat flatter in the older age groups and more symmetrical in the younger age groups but on the whole they show a fairly smooth distribution The calculated mean and normal range are indicated on each curve

In Table XVI the calculated mean the standard deviation and the coefficient of variation are shown The latter two indicate the degree of individual diversity or scatter of the blood pressure readings

Mean Blood Pressure Values

Mean blood pressure readings both systolic and diastolic increase with age in both sexes (Table XVI Figure 29) The average systolic reading in men shows a fairly smooth rise up to the age of fifty after fifty, the rise is accelerated In women the rise in the average systolic pressure with age is somewhat less smooth, but it also is accelerated after the age of fifty. After the age of twenty, the rise of the diastolic pressure with age is fairly steady in both sexes a systematic acceleration of the average diastolic pressure is not found over any broad age period

TABLE XVI —SYSTOLIC AND DIASTOLIC BLOOD PRESSURE READING BY SEX AND AGE

Sex Age	Systolic			Diastolic		
	Mean	Stand Dev	Coef of Variation	Mean	Stand Dev	Coef of Variation
Males						
16	118 4	12 17	10 28	72 9	10 33	14 17
17	121 0	12 88	10 64	74 4	9 36	12 58
18	119 8	11 95	9 97	74 4	10 03	13 48
19	121 8	14 99	12 31	74 6	10 29	13 79
20–24	122 9	13 74	11 18	76 0	9 93	13 07
25–29	125 1	12 58	10 06	7 8	8 99	11 54
30 34	126 1	13 61	10 79	78 5	9 69	12 33
35–39	127 1	14 20	11 17	80 4	10 42	12 96
40–44	129 0	15 07	11 69	81	9 53	11 74
45–49	130 0	16 93	13 02	82 0	10 81	13 18
50–54	134 5	19 21	14 29	83 4	11 31	13 56
55–59	137 8	18 80	13 64	84 0	11 40	13 57
60–64	141 8	21 11	14 89	84 5	12 36	14 63
Females						
16	116 1	12 10	10 42	2 3	9 55	13 21
17	116 0	11 51	9 92	72 0	9 16	12 72
18	116 3	11 42	9 82	71 8	8 60	11 98
19	115 1	11 87	10 31	71 1	8 93	12 56
20–24	115 7	11 83	10 22	71 7	9 67	13 49
25 29	116 8	11 43	9 79	73 7	9 05	12 29
30–34	119 8	13 97	11 66	74 9	10 78	14 39
35–39	123 9	13 85	11 18	78 0	10 01	12 83
40–44	127 0	17 07	13 44	79 5	10 60	13 33
45–49	130 6	19 47	14 91	81 5	11 63	14 27
50–54	137 3	21 29	15 51	83 5	12 36	14 80
55–59	138 5	21 40	15 45	83 5	11 72	14 04
60–64	144 0	22 33	15 51	85 0	12 95	15 24

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Among boys between the ages of sixteen and nineteen an upward trend in the averages of both the systolic and the diastolic pressures is found Among girls on the other hand both the systolic and the diastolic pressures remain practically unchanged between the ages of sixteen and

eighteen and continue to be unchanged until the age of twenty five This difference may be due to the fact that boys mature between the ages of sixteen and nineteen, whereas girls mature earlier.[2] Boys at that time become heavier and are much more active than are girls of like years, and it has been long recognized that a rapid rise in blood pressure occurs during puberty and adolescence

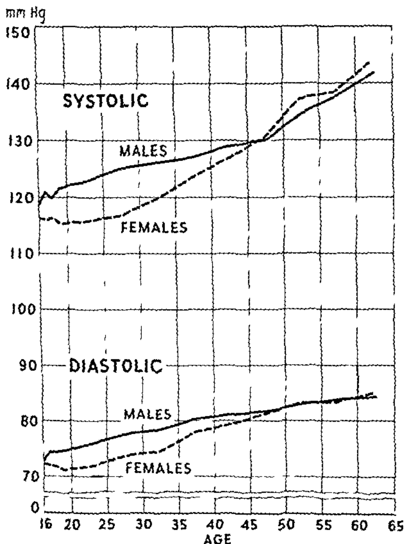


FIG 29

7

In the present study the averages of the systolic pressures among men *ranged from 118 4 mm mercury, at the age of sixteen to 141 8 mm* in the sixty to sixty four year group the average diastolic pressures ranged from 72 9 mm mercury at the age of sixteen to 84 5 mm in the sixty to *sixty four year group Among women the averages of the systolic pres* sures ranged from 115 1 mm mercury at the age of 19 to 144 0 mm in the sixty to sixty four year group the average diastolic pressures ranged *from 71 1 mm mercury at the age of nineteen to 85 0 mm* in the sixty to sixty four year group

Up to the age of forty five the average systolic pressure was higher *among men than among women Between the ages of twenty five and* twenty nine this difference was 8 mm mercury After the age of forty five the average blood pressure of women was higher but the difference *between the sexes was small It has long been known that the blood pres* sure increases in both sexes after the age of forty five The average diastolic readings among men were also higher than among women up *to the age of fifty The maximum difference about 4 mm mercury* was found between the 20 and 24 years *After the age of fifty* the diastolic averages were about the same in both sexes the differences which *were found were neither consistent nor large*

The figures for the standard deviation given in Table XVI indicate that there is an absolute increase in the range of the readings with increas ing age The relative variation moreover as measured by the coefficient of variation also has an upward trend with age This increase begins after the age of twenty five and is found in both the systolic and the diastolic readings For example among men between the ages of twenty five and twenty nine the standard deviation of the systolic readings around the mean is 12 58 mm or 10 per cent of the mean figure while among men between the ages of sixty to sixty four the standard devia tion is 21 11 mm, or nearly 15 per cent of the mean figure

The absolute range of the diastolic readings is of course, smaller than is the range of the systolic readings The relative variation in both sexes however is larger for the diastolic than for the systolic readings up to the age of forty thereafter the systolic pressures have a somewhat larger relative variation but the differences are small In men between the ages of thirty and thirty four for example the standard deviation of the systolic pressure from the mean was 13 61 mm mercury (10 8 per cent of the mean value) while the standard deviation of the diastolic pressure was 9 68 mm (12 3 per cent of the mean value) *In men be* tween the ages of fifty and fifty four however the standard deviation of the systolic pressure was 19 21 mm mercury (14 3 per cent of the mean value) while the *standard deviation of the diastolic pressure was 11 31* mm (13 6 per cent of the mean value)

The range of blood pressure readings both absolutely and relatively is greater among women *than men after the age of forty* For example

among men between forty and forty four years of age the standard deviation of the systolic pressure is 15 07 mm mercury and the coefficient of variation is 11 7 per cent the corresponding figures for women are 17 07 mm mercury and 13 4 per cent Similarly the diastolic figures are 9 53 mm mercury (11 7 per cent) among men and 10 60 mm (13 3 per cent) among women

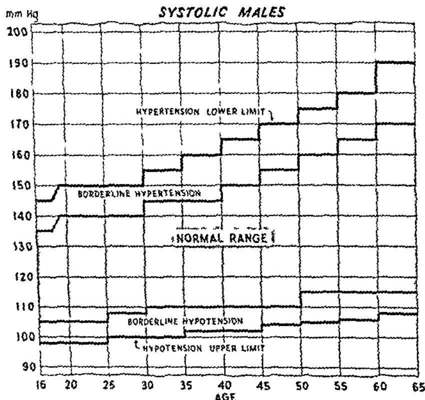


Fig 30

In the fourth decade the differences in the actual and relative variability of blood pressure readings between the sexes show no constant pattern In subjects who are less than thirty years of age the figures tend to be the reverse of those found in subjects who are over fifty i e the figures for men are higher than are the figures for women The differences that do occur however are generally smaller than those found in the older age groups A possible exception occurs among those who are

under twenty It is likely that the greater variability in the blood pressure among young males is a reflection of the later age at which they attain maturity

From Figure 29 and Table XVI several broad conclusions may be drawn

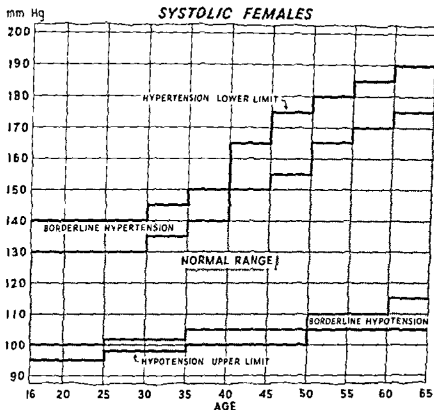


Fig 31

A) *The mean blood pressure reading* both systolic and diastolic increases with age in both sexes The increase in the systolic pressure is more rapid after the age of fifty There is no systematic acceleration of the diastolic pressure over any broad age period

B) *The range of the blood pressure readings* also increases with age as does the relative variation measured by the coefficient of variation This increase begins after the age of twenty five and affects both the systolic and the diastolic readings

C) *The absolute range of the diastolic readings* is smaller than is the range of the systolic readings

D) *The range of blood pressure readings* both absolutely and relatively is greater in women than in men after the age of forty In the fourth decade the differences between the two sexes show no constant pattern Under the age of thirty the figures tend to be reversed these in men being higher than those in women

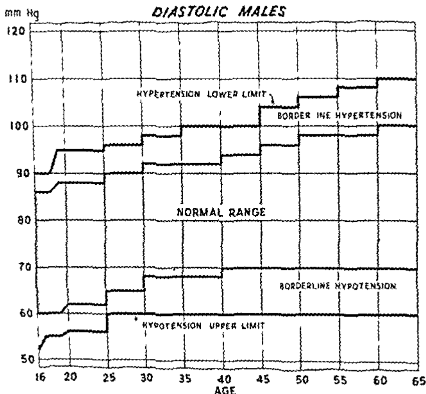


Fig 32

The normal range of the systolic and the diastolic pressure as determined by this study is given in Figs 30–33 and Tables XIV–XVI

The normal range of the systolic pressure is wide It increases with age from 30 to 55 mm mercury in males and from 30 to 60 mm mercury in females The upper limit of the normal systolic pressure is slightly

lower in females under the age of forty, than in males after the age of fifty it is higher in the females Thus in the sixteen to twenty year group the normal systolic range is 105 to 135 mm mercury in males and 100 to 135 mm mercury in females In the sixty to sixty four year group it is 115 to 170 mm mercury in males and 115 to 175 mm mercury in females

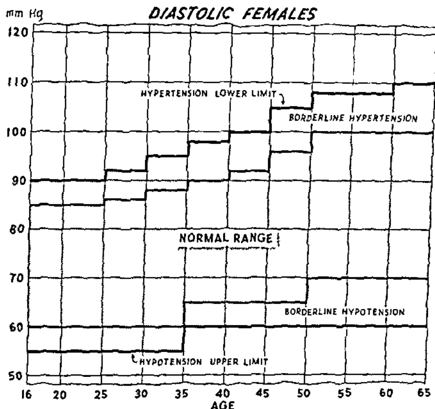


FIG 33

The normal range of the diastolic pressure is not as wide as that of the systolic varying from 26 to 30 mm mercury in males and from 25 to 30 mm in females Furthermore the increase of the diastolic pressure with age is less marked than is the increase of the systolic pressure this accounts for the well known tendency of the pulse pressure to increase with age Thus *in the sixteen to twenty year group* the normal diastolic range is sixty to eighty six mm mercury in males and 60 to 85 mm

mercury in females. In the sixty to sixty four year group it is 70 to 100 mm mercury in both males and females. The borderline group is indicated in both figures. It necessarily includes all the cases which fall between the upper limit of the normal range and the lower limit of hypertension as well as those which fall between the lower limit of the normal range and the upper limit of hypotension. Cases in this borderline group must be judged individually. They may belong to the normal, the hypertensive or the hypotensive group depending entirely upon their clinical status. This will be more fully discussed in the final chapter.

TABLE XVII.—MEAN BLOOD PRESSURE READINGS IN SELECTED STUDIES.

MALES

	Systolic				*Diastolic*			
Age	*Present Study*	*Gover*	*Russek*	*Robinson & Brucer*	*Present Study*	*Gover*	*Russek*	*Robinson & Brucer*
20–24	122 9	132 5		119 0	76 0	76 8		70 8
25–29	125 1	130 9		118 5	7 8	77 1		72 0
30–34	126 1	131 3		117 5	78 5	77 2		72 7
35–39	127 1	132 1		117 6	80 4	79 1		74 0
40–44	129 0	132 4	133 3	120 1	81 2	79 9	84 8	75 7
45–49	130 0	138 7	137 0	122 7	82 0	83 1	86 6	77 0
50–54	134 5	141 4	138 9	125 6	83 4	83 7	87 0	77 3
55–59	137 8	151 9	142 4	129 6	84 0	88 9	8 7	78 2
60–64	141 8	154 4	147 7	131 7	84 5	86 7	87 6	77 5

FEMALES

	Systolic			*Diastolic*		
20–24	115 7	124 8	108 4	71 7	76 5	65 4
25–29	116 8	127 5	110 2	73 7	8 4	67 1
30–34	119 8	128 7	111 6	74 9	80 4	69 0
35–39	123 9	133 4	114 4	78 0	82 6	70 7
40–44	127 0	141 0	119 0	9 5	85 7	73 2
45–49	130 6	149 2	125 4	81 5	89 5	75 4
50–54	137 3	158 0	125 8	83 5	90 9	75 7
55–59	139 5	167 4	138 2	83 5	93 5	9 0
60–64	144 0	162 9	142 8	85 0	89 1	81 0

A Comparison of Blood Pressures Found in Various Surveys

Figure 34 and Table XVII compare the systolic and diastolic averages for men and women in the present study with those found in other selected investigations The reports chosen for this purpose are those from Gover's[25] study on members of white farm families who received assistance from the Farm Security Administration of Robinson and Brucer[9] on life insurance policyholders who were examined by the Life Extension

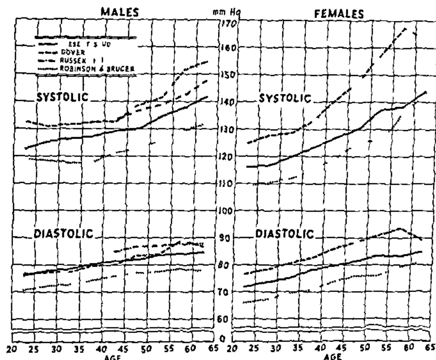


Fig 34

Master Dublin and Marks The Normal Blood Pressure Range and Its Clinical Implications courtesy of J A M A

Institute in Chicago and of Russek[40] and his associates on merchant seamen active or retired coast guardsmen candidates for civil service and an older group of city indigents The Robinson and Brucer data include their entire experience and not only that limited to cases with readings under 140/90 mm mercury It is readily seen in the graph that the averages obtained from our study are about intermediate between those obtained from the other sources When the data from other numerous studies were examined the averages obtained in the present series were also found to occupy an approximately intermediate position

TABLE XVIII — SYSTOLIC AND DIASTOLIC BLOOD PRESSURE ACCORDING TO WEIGHT GROUPS

Sex and Age	Systolic								Diastolic							
	10% or More Underweight		Average Weight		Overweight				10% or More Underweight		Average Weight		Overweight			
					10 to 49%		50% or More						10 to 49%		50% or More	
	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev
Male																
16	115.8	12.49	119.1	11.77	117.2	11.89	123.9	13.05	71.5	10.16	[illegible]	9.86	71.7	11.89	77.1	10.55
17	118.8	14.63	120.9	12.13	122.5	13.38	124.5	13.37	72.0	9.89	[illegible]	8.92	76.9	8.85	77.2	[illegible]
18	116.7	11.99	120.0	11.86	122.3	10.47	124.3	12.63	71.2	10.80	74.8	9.61	77.5	9.76	76.2	9.37
19	118.1	13.07	[illegible]	15.00	[illegible]	10.40	128.4	14.93	71.4	11.61	74.6	9.93	77.4	8.63	81.3	8.22
20-24	119.5	12.39	123.7	14.46	124.1	12.36	126.2	12.29	74.1	8.77	75.4	10.13	78.9	9.49	82.2	9.05
25-29	125.2	12.03	124.1	12.65	125.8	11.87	127.2	14.73	76.0	8.64	77.2	8.93	[illegible]	9.33	83.0	9.97
30-34	[illegible]	12.47	126.0	11.56	128.7	14.11	132.8	13.31	76.3	9.51	78.4	[illegible]	80.5	10.15	83.5	9.42
35-39	124.3	14.76	126.3	12.86	129.9	[illegible]	137.0	17.66	[illegible]	9.67	80.0	9.40	83.5	11.25	81.9	12.52
40-44	[illegible]	14.94	129.4	14.11	[illegible]	16.79	133.3	[illegible]	79.6	9.35	81.2	[illegible]	83.3	[illegible]	85.8	9.76
45-49	127.7	17.82	130.3	15.85	132.1	18.78	136.0	12.87	80.1	[illegible]	81.8	10.93	85.0	11.30	87.9	10.22
50-54	[illegible]	17.36	134.5	[illegible]	136.7	18.24	139.4	19.73	81.9	[illegible]	83.3	11.10	85.0	11.02	89.2	12.40
55-59	134.9	18.06	138	17.49	143.1	22.81	145.5	21.89	82.0	10.26	84.0	11.08	[illegible]	13.42	91.9	13.09
60-64	[illegible]	20.2	142.1	20.89	[illegible]	22.42	148.3	22.59	82.6	11.83	84.6	12.33	87.4	11.93	89.4	14.41
Female																
16	115.0	9.03	115.3	11.99	116.0	10.74	122.2	15.95	[illegible]	7.16	72.0	9.91	73.8	[illegible]	[illegible]	12.64
17	113.3	11.33	115.9	10.06	116.5	11.47	124.1	13.65	70.5	8.19	[illegible]	8.66	73.1	9.68	75.5	12.93
18	113.0	10.63	116.2	11.05	118.0	12.15	121	12.12	69.5	8.85	71.9	8.11	[illegible]	9.47	74.7	8.43
19	[illegible]	10.37	114.5	11.74	116.4	11.72	[illegible]	12.07	69.2	9.43	[illegible]	9.09	[illegible]	8.85	74.4	7.84
20-24	113.7	11.18	115.3	11.25	[illegible]	10.36	123.4	15.02	70	8.98	71.6	9.50	72.2	[illegible]	75.9	11.33
25-29	114.5	11.69	116.4	10.14	118.6	10.94	123.6	13.74	71.8	9.39	73	9.12	75.5	[illegible]	[illegible]	10.22
30-34	116.1	13.01	118.5	[illegible]	125.0	17.60	126.5	14.56	72	11.39	[illegible]	9.28	77.2	11.39	81.7	10.22
35-39	120.7	12.39	123.3	13.93	126.1	[illegible]	[illegible]	13.34	75.8	10.12	77.2	[illegible]	79.7	[illegible]	92.0	10.00
40-44	122.4	[illegible]	[illegible]	15.12	128.7	16.76	136.1	[illegible]	[illegible]	9.06	78.2	[illegible]	82.0	11.97	86.7	11.52
45-49	123.6	[illegible]	131.0	19.02	136.9	[illegible]	137.3	19.3	77.7	10.56	81.4	11.42	85.3	11.77	85.5	11.81
50-54	132.4	19.85	135.9	19.46	141.4	24.63	140.6	[illegible]	80.3	10.91	[illegible]	10.95	86.4	[illegible]	89.1	12.82
55-59	135.1	19.92	137.3	[illegible]	143.4	20.94	147.3	23.94	81.4	10.3	83.2	11.07	86.3	13.10	87.6	13.46
60-64	141.0	21.58	[illegible]	[illegible]	154.8	[illegible]			82.9	12.49	82.9	12.12	90.2	13.04	*	

Classified according to deviation from average weight for sex, height and age. Standards used are the averages from the Medico-Actuarial Mortality Investigation 1912 for ages 25 and over and from the Medical Impairment Study 1929 for ages under 25.

2 INFLUENCE OF WEIGHT ON BLOOD PRESSURE

Data showing the relation of weight to blood pressure are given in Table XVIII

The subjects were divided into four weight groups

Underweight	10 per cent or more below average
Average Weight	less than 10 per cent above or below average
Overweight moderate	10-24 per cent above average
Overweight severe	25 per cent or more above average

The standard tables of average weight for height and age of men and women were used These tables are based on the average weight of 100 000 consecutive insurance cases It is apparent that weight is an important and consistent factor in blood pressure changes (Table XVIII) With an increase in weight there is a progressive increase in the averages of the systolic and diastolic blood pressure, regardless of age or sex This is in conformity with the known effect of weight on blood pressure *which has already been discussed* *Reduction in weight therefore is a* routine therapeutic procedure for patients with hypertension

The difference in the mean systolic blood pressure at each extreme of the underweight and overweight groups exceeded 10 mm mercury in some instances the difference in the diastolic pressure was almost as great The differences in the mean systolic and diastolic pressure among women of each extreme weight group particularly after the age of forty were even greater than those among men *Absolute and relative variations* in blood pressures as measured by the standard deviation and the coefficient of variation also tended to increase with weight particularly after the age of 40 years In general the greatest contrast in the mean pressures was found in the older age groups and among women

3 INFLUENCE OF HEIGHT ON BLOOD PRESSURE

The subjects were divided into three groups—short medium and tall—the height being tabulated at the nearest inch

	Male	*Female*
Short	5 5 and less	5 1 and less
Medium	5 6 - 5 10	5 2 -5′6″
Tall	5 11 and over	5 7 and over

No clear relationship between height and blood pressure was found Table XIX *The mean systolic blood pressure was consistently* highest in tall men between the ages of thirty five and thirty nine It was higher

TABLE XIX.—SYSTOLIC AND DIASTOLIC BLOOD PRESSURE ACCORDING TO STATURE

	Systolic						Diastolic					
	Short		Medium		Tall		Short		Medium		Tall	
Sex and Age	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev
Males												
16	11 3	12.44	118.3	12.57	120.7	9.43	71.9	11.24	72.6	10.39	75.6	9.02
17	119	12.45	120.6	11.91	123.3	15.58	73.6	10.77	74.3	9.14	75.3	9.77
18	115.6	10.01	119.8	11.56	123.7	13.46	73.3	10 6	74.0	10.02	77.0	7.37
19	119.7	0.86	121.3	13.57	124.6	14.17	72.8	12.16	74.4	10.20	76.4	8.90
20-24	120.1	11.76	123.0	14 6	124.2	1 21	75.7	10.00	75.5	10.08	77.2	9.42
25-29	123.4	12.93	125.1	12.67	125.8	12.08	77.3	9.82	8 2	8.61	7 3	9.44
30-34	123.8	14.90	126.1	12.91	127.1	14.59	77.8	12.19	8 8	9.32	78.3	9.29
35-39	126.4	14.33	176.2	13.59	130.8	15.77	9 9	10.01	80.2	10.38	81.8	10.81
40-44	128.2	17.17	1 9 2	14.80	128.8	14.01	82.5	9.64	80.9	9.57	81.2	9 3
45-49	131.0	21.05	130.0	16.30	129.0	14.16	82.7	13.43	81.9	10.31	81.7	9.53
50-54	133.4	18.23	135.2	19.97	132.9	1 04	81.8	10.35	83.6	11.95	83.8	9.51
55-59	139.9	19.97	137.3	18.32	137.6	19.38	84.1	11.95	84.0	11.21	83.8	11.61
60-64	139.6	19.69	142.1	1 51	143.4	21.0	84.5	11.75	84.1	12.40	86.6	12.77
Females												
16	113.0	15.96	114.9	9.99	119.5	14.95	72.9	12.21	2	9.98	1 4	6.83
17	114.7	8.15	115.8	11.20	118.1	14.38	70.7	9.56	1 6	8.74	74.8	10.20
18	115.8	14 3	116.5	10.88	115.6	10.74	0 7	8.60	72.0	8.57	71.6	9.69
19	113.4	11	115.0	11.81	117.1	12.00	0 3	8.98	71.0	9.90	72.5	9.33
20-24	115.5	12.32	115.9	11.46	115.5	12.92	69.9	9 8	71.7	9.50	3 2	10.00
25-29	114.6	10.04	117.1	11.49	117.5	12.12	72.6	7.90	73.8	9.20	74.5	9.36
30-34	1 0 4	15.09	119.3	13.27	121.8	15.77	74.3	12.99	74.5	9.77	77.5	12.34
35-39	123.4	14.61	123	13.51	125.4	14.60	78.1	9.28	77.7	9.81	9 1	11.08
40-44	128.2	17.17	129.2	14.80	128.8	14.01	9 8	11.12	9 2	10.57	80.8	10.10
45-49	128.9	1 46	131.7	19.07	127.0	19.65	80.0	12.93	81.8	11.31	81.3	11.67
50-54	138.4	2 8	137.2	21.40	136.9	19.39	83.7	12.36	83.6	12.66	82.9	10.53
55-59	140.1	22.12	137.2	20.36	145.8	25.90	85.0	12.57	82.6	10.96	87.7	14.94
60-64	145.8	23.5	144.7	22.60			87.3	15.59	84.4	12.50	*	

* Not significant; less than 20 cases

TABLE XX.—SYSTOLIC AND DIASTOLIC BLOOD PRESSURE ACCORDING TO HEIGHT AND WEIGHT GROUPS

	Systolic						Diastolic					
	Short		Medium		Tall		Short		Medium		Tall	
Sex, Age, Weight Group	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev	Mean	Stand Dev
Males												
20–29												
10% or more underweight	120 8	13 29	122 5	13 10	123 2	10 83	74 3	9 48	75 6	9 17	75 6	7 54
Average weight	121 5	12 43	124 4	14 08	124 4	12 39	76 6	9 62	76 0	9 44	77 2	9 85
10–24% overweight	123 2	9 78	125 2	11 39	126 0	13 36	78 4	9 29	9 7	8 38	78 0	9 67
25% or more overweight			125 4	11 83					83 0	8 57		
30–39												
10% or more underweight	125 2	16 19	122 7	12 67	125 1	14 59	75 7	11 23	76 8	9 13	77 1	9 91
Average weight	124 1	14 86	125 9	12 67	128 3	13 54	79 7	10 39	78 9	9 31	80 1	8 01
10–24% overweight	127 2	11 10	128 5	13 54	133 5	15 06	79 9	11 43	82 3	10 37	82 3	11 89
25% or more overweight			134 6	13 38					86 0	10 8		
40–49												
10% or more underweight	128 3	22 63	126 8	15 12	128 9	14 02	81 9	11 97	9 2	9 01	80 1	9 04
Average weight	128 5	15 66	130 6	15 06	129 4	14 06	81 4	11 77	81 4	9 93	81 6	10 11
10–24% overweight	132 0	23 15	130 9	16 87	130 0	13 42	84 3	10 68	84 3	10 30	83 0	6 97
25% or more overweight			133 9	16 24					85 9	10 94		
50–59												
10% or more underweight	136 3	19 25	134 2	17 67	131 2	16 48	81 8	11 52	82 5	10 95	80 6	9 23
Average weight	135 1	18 42	136 3	17 23	137 4	19 85	83 3	9 80	83 4	11 47	85 0	10 68
10–24% overweight	139 5	21 53	139 7	20 86			83 6	14 61	86 4	11 43		
25% or more overweight			140 8	22 29					90 4	14 76		

F m l s												
20–29												
10% or more underw ght	113 6	10 56	114 0	11 32	115 2	13 28	69 5	8 64	71 4	9 24	70 9	9 61
A rag e ght	113 6	11 06	116 2	10 61	114 9	11 25	70 5	8 65	72 5	8 87	74 1	9 55
10–24% r ght			116 8	11 11	120 4	9 46			72 5	9 97	76 9	7 94
25% o m ght	122 3	13 24	124 5	13 39	120 3	13 92	76 7	9 39	77 2	10 9	73 7	11 89
30 39												
10% r m r und e ght	118 0	14 42	117 9	11 95	119 5	14 89	73 6	12 61	74 1	9 89	74 6	12 82
A erag ght	122 5	13 91	119 8	12 10	124 0	15 89	76 2	10 09	74 7	9 34	77 6	9 24
10–24% o er ght			125 8	15 64	124 8	14 80			78 0	9 49	80 4	12 92
25% m r o e ght	124 8	11 83	127 7	14 61	130 1	11 97	78 7	9 71	81 8	9 90	85 7	10 28
40 49												
10% m re und w ght	120 5	15 66	124 0	15 94	120 2	22 63	75 1	10 81	77 8	9 38	75 6	10 20
A ag ght	130 0	20 91	128 6	16 53	128 4	17 67	80 1	12 21	9 7	10 36	80 4	9 25
10–24% er gl t	126 6	16 88	132 3	18 60	136 4	18 80	83 6	11 93	83 5	12 51	83 3	9 85
25% n re rw ght	137 7	16 44	135 9	20 07	139 2	21 78	87 3	8 88	85 2	11 98	89 4	11 84
50 59												
10% m re n ler ght	137 3	21 06	132 9	19 40	134 2	16 96	80 6	11 93	80 7	10 43	82 3	9 9
A g ght	139 3	22 36	135 8	19 34	137 8	23 17	85 6	12 32	82 1	10 39	83 9	11 99
10–24% o ght	144 3	23 27	140 0	22 41	154 2	21 89	85 5	13 9	86 1	14 10	89 0	15 21
25% o mer er e ght	139 4	16 74	149 3	22 53			89 0	10 09	87 8	13 39		

Not gn fi ant l s than 20 ase

in men of medium height than in short men up to the age of thirty four After the age of forty the differences in the mean systolic pressures of men according to height were not significant Among women there was no apparent correlation between mean systolic readings and height

The mean diastolic readings in men showed no definite pattern according to height except in those under the age of twenty Among these young men there was a consistent increase in the averages with an increase in height the difference being a little over 3 mm mercury The average diastolic blood pressure of tall women was *consistently higher* than that of shorter women at most ages up to forty five years Beyond that age the pattern was not consistent

Relative Influence of Height and Weight

In order to clarify further the influence of body build on blood pressure the data for short medium and tall men were analyzed separately according to the four weight classes (Table XX and see appendix Table 4) It is evident from this detailed analysis also that weight has a consistent influence on the level of the blood pressure The averages of both the systolic and the diastolic pressures in every height class tended to rise with an increase in weight However the effect of height itself on blood pressure seemed to be negligible because there was no systematic trend in the averages due to height in the several weight groups

4 INCIDENCE OF HYPERTENSION

In view of the differences of opinion concerning the definition of hypertension its incidence has been computed according to various definitions some of which are based on the separate systolic and diastolic readings and some on combinations of them The groupings based on the combined systolic and diastolic readings include cases in which either reading was within the specified limits For example the hypertensive group (140/90 mm mercury or over) includes those with readings of 138/90 or 142/88 mm mercury

Table XXI and Figure 35 show the incidence of hypertension according to the several standards It is readily seen that the frequency of so called hypertension increases steadily with age Minor deviations from the upward trend are unimportant and may be attributed to the size of the samples in the particular categories involved Hypertension of mild degree was fairly common at comparatively young ages particularly among men About one fifth of the men between the ages of twenty and twenty nine had readings of 140/90 mm mercury or higher However hypertension of more severe degree was relatively infrequent at these ages, readings of 150/100 mm mercury or more occurred in only one of every 20 cases

TABLE XXI —P E EN E OF HY RTEN N ACCO D G O S N OF D FI ITIONS, Y SEX ND AGE

S d Age Group	Per Cent 140/90 or over	1 ?/ 0 or over	1 ? ? er	150/100 or over	1?? 10 er	Systolic 1 0 or over	Diastolic 9(or over	Di t lic ? er	Diastolic 100 or over
Males									
16–19	13 1	9	4 6	4 0	5	3 3	7 0	1 8	1 0
?0 4	18 3	1 5	6 3	4 9	7	3 ?	10 0	2 8	1 2
25–?9	?0 4	14 5	5 ?	5 1	6	3 8	12 7	3 1	1 8
30–34	24 6	17 9	8 4	6 5	9	7	14 6	3 8	1 7
3 39	29 1	3 3	1 1	9 5	1	7 3	0 8	7 3	4 3
40–44	3 8	2 4	12 9	10	1 1	9 7	??	7 8	3 8
45–49	37 9	?9 6	18 4	15 8	3 6	13 4	2? 3	11 9	7 7
?0 4	46	37 8	4 5	?? 2	4 3	?0	3 1	13 8	8 6
5 9	54 4	41 8	29 1	27 7	6 4	8 3	34	1	12 7
60 64	60 3	48 5	38 0	36 9	8	34 ?	38	?0 0	14 9
Females									
16–19	5 3	4 0	1 7	1 4		1 1	3 2	8	4
?0–24	6 9	6 1	1 7	1 3	1	1 3	8	9	3
25– 9	8 4	6 7	2 1	2 0	?	1 5	6	1	1
30–34	13 1	10 6	5 1	3 6	9	3 4	10 0	3 6	1 9
35–39	20 8	16 4	7 1	6 1	1 1	5 3	14 8	4	2 9
40–44	8 5	0	12 5	11 1	2 7	9 6	18 0	7 6	4 7
45–49	39 4	30 1	?0 6	19 0	1	17 3	?7 0	1 8	8 9
50 54	50 6	41 8	30	?8 8	8 4	8 ?	37 4	17 0	12 0
55–59	5 2	42 1	33 4	31 0	? ?	?3 7	33 7	16 7	11 0
60–64	64 4	1 8	43	40 8	13 1	39 8	33 3	?3 0	15 2

R d gs mm Hg (se n l d d f tl th ? t l l d t l is a tl the pe fed l m t

Hypertension of at least mild degree was common in middle aged and old people Blood pressures of 140/90 mm or higher were present in about 40 per cent of both men and women between the ages of forty five and forty nine and in 60 per cent of those between the ages of sixty and sixty four Readings of 150/100 mm or more were found in nearly 20 per cent of the subjects under the age of forty five Thereafter the incidence of such readings rose steadily in both sexes to over 35 per cent in those between the ages of sixty and sixty four Whatever definition of hypertension is used the condition was found more frequently in men up to the age of forty five and more frequently in women thereafter

in men of medium height than in short men up to the age of thirty four After the age of forty the differences in the mean systolic pressures of men according to height, were not significant Among women, there was no apparent correlation between mean systolic readings and height

The mean diastolic readings in men showed no definite pattern according to height except in those under the age of twenty Among these young men there was a consistent increase in the averages with an increase in height the difference being a little over 3 mm mercury The average diastolic blood pressure of tall women was consistently higher than that of shorter women at most ages up to forty five years Beyond that age the pattern was not consistent

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pressure at sixteen years of age is between 105–135 mm mercury at seventeen the range is between 105–135 mm at eighteen years 105–135 mm at nineteen years 105–140 mm at twenty to twenty four years 105–140 mm at twenty five to twenty nine years 108–140 mm, at thirty to thirty four years of age 110–145 mm at thirty five to thirty nine years 110–145 mm at forty to forty four years 110–150 mm at forty five to forty nine years 110–155 mm at fifty to fifty four years 115–160 mm at fifty five to fifty nine years 115–165 mm at sixty to sixty four years of age 115–170 mm mercury In females the normal range of systolic blood pressure begins at sixteen years of age with 100–130 mm mercury at seventeen years 100–130 mm at eighteen years 100–130 mm at nineteen years 100–130 mm at twenty to twenty four years 100–130 mm at twenty five to twenty nine years 102 130 mm at thirty to thirty four years 102–135 mm at thirty five to thirty nine years 105–140 mm at forty to forty four years 105–150 mm at forty five to forty nine years 105–155 mm at fifty to fifty four years 110 165 mm at fifty five to fifty nine years 110–170 mm and at sixty to sixty four years of age 115 175 mm of mercury The normal range for diastolic pressure in males is at sixteen years of age 60–86 mm mercury at seventeen years 60–86 mm at eighteen years 60–86 mm at nineteen years 60–88 mm at twenty to twenty four years 62–88 mm at twenty five to twenty nine years of age 65–90 mm at thirty to thirty four years 68–92 mm at thirty five to thirty nine years 68–92 mm at forty to forty four years 70–94 mm at forty five to forty nine years 70–96 mm at fifty to fifty four years 70–98 mm at fifty five to fifty nine years 70–98 mm at sixty to sixty four years of age 70–100 mm mercury In females the normal range for diastolic pressure is at sixteen years of age 60–85 mm at seventeen years 60–85 mm at eighteen years 60–85 mm at nineteen years 60–85 mm at twenty to twenty four years 60–85 mm at twenty five to twenty nine years 60–86 mm at thirty to thirty four years 60–88 mm at thirty five to thirty nine years 65–90 mm at forty to forty four years 65–92 mm at forty five to forty nine years 65–96 mm at fifty to fifty four years 70–100 mm at fifty five to fifty nine years 70–100 mm and at sixty to sixty four years of age 70–100 mm mercury Blood pressures falling in the borderline range (between the upper limit of normal and the lower limit of hypertension) may be either normal or abnormal and each patient should be thoroughly studied for the presence of vascular disease before concluding whether the blood pressure is normal or not Readings above the lower limit of hypertension are not *ipso facto* evidence of the existence of clinical hypertension though the chances are very high that hypertension exists

3 The effect of weight and height on the blood pressure was also investigated With an increase in weight there was a progressive increase in the averages of the systolic and diastolic pressure regardless of age and sex Height was found to have no influence on the blood pressure

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APPENDIX TO CHAPTER V

TABLE 1.—SYSTOLIC AND DIASTOLIC BLOOD PRESSURE READINGS BY SEX AND AGE SHOWING 80% (1.282 STANDARD DEVIATION) LIMITS

Age	Systolic			Diastolic		
	−1.28	Mean	+1.28	−1.28	Mean	+1.28
MALE						
16	102.8	118.4	134.0	59.7	72.9	86.1
17	104.5	121.0	13[illegible].5	62.4	74.4	86.4
18	104.5	119.8	135.1	61.5	74.4	87.3
19	102.6	121.8	141.0	61.4	74.6	87.8
20–24	105.3	122.9	140.5	63.3	76.0	88.7
25–29	109.0	125.1	141.2	66.3	7[illegible].8	89.3
30–34	108.7	126.1	143.6	66.1	78.5	90.9
35–39	108.9	127.1	145.3	67.0	80.4	93.8
40–44	109.7	129.0	148.3	69.0	81.2	93.4
45–49	108.3	130.0	151.7	68.1	82.0	9[illegible].9
50–54	109.9	134.5	159.1	68.9	83.4	97.9
55–59	113	137.8	161.9	69.4	84.0	98.6
60–64	114.7	141.8	168.9	68.7	84.5	100.4
FEMALE						
16	100.6	116.1	131.6	60.0	72.3	84.5
17	101.2	116.0	130.8	60.3	72.0	83.7
18	101.7	116.3	130.9	60.8	71.8	82.8
19	99.9	115.1	130.3	59.7	71.1	82.6
20–24	100	115.7	130.9	59.3	71.7	84.1
25–29	102.2	116.8	131.5	62.1	73.7	85.3
30–34	101.9	119.8	137.7	61.1	74.9	88.7
35–39	106.1	123.9	141	65.2	78.0	90.8
40–44	105.1	127.0	148.9	65.9	79.5	93.1
45–49	105.6	130.6	155.6	66.6	81.5	96.4
50–54	110.0	137.3	164.6	67.7	83.5	99.4
55–59	111.1	138.5	165.9	68.5	83.5	98.5
60–64	115.4	144.0	172.6	68.4	85.0	101.6

TABLE 2.—DISTRIBUTION OF SYSTOLIC BLOOD PRESSURE READINGS, BY SEX AND AGE

Data Derived from Medical Examinations of Employees and Applicants of 11 Large Industrial Plants and Army Air Field (Civilians only) Sample of Entire Experience

Males

Systolic Blood Pressure in mm. Mercury	Total 755 100.0	16 100.0	17 100.0	18 100.0	19 100.0	20-24 100.0	25-29 100.0	30-34 100.0	35-39 100.0	40-44 100.0	45-49 100.0	50-54 100.0	55-59 100.0	60-64 100.0
						Per Cent of Total								
76 and under	.0		—	.2	—	—		—			—		—	
77-81	—	—	—	—	—	—		—	—	—	—	—	—	—
82-86	.0	—	—	—	—	—		—	—	—	.2	—	—	—
87-91	.4	.5	.9	.7	.6	.7	.1	.5		.2	.2	.2	—	—
92-96	.5	1.4	.3	.8	.6	.5	.4	.2	.2	.4	—	.4	.2	.2
97-101	2.4	5.2	2.3	4.3	1.8	3.3	1.3	2.4	1.3	1.7	1.8	1.3	1.2	1.5
102-106	3.9	9.5	5.1	6.7	6.1	4.6	3.0	3.0	3.7	2.1	2.8	.7	1.2	.7
107-111	9.3	12.9	12.0	11.6	14.4	12.2	10.0	9.2	9.5	6.3	8.5	5.2	4.0	4.1
112-116	9.1	15.8	13.6	11.6	10.0	8.6	7.8	5.9	9.0	7.9	4.7	5.0	3.0	2.0
117-121	18.7	21.3	24.0	26.0	22.1	20.7	21.3	18.1	17.6	15.9	16.8	14.8	11.4	9.7
122-126	12.4	11.8	16.0	14.1	12.3	13.9	14.4	15.3	12.1	11.9	10.3	10.8	9.8	6.7
127-131	13.4	8.8	12.4	10.6	11.6	15.3	16.9	15.5	16.1	15.5	13.6	12.7	12.0	11.6
132-136	7.3	4.3	3.8	4.3	5.6	7.4	8.9	8.4	8.2	12.3	12.1	7.7	6.8	5.9
137-141	8.9	3.8	4.6	5.6	4.7	6.1	7.6	11.0	9.3	11.2	9.5	12.7	15.2	15.4
142-146	1.6	2.3	.4	1.1	2.2	2.1	3.5	3.1	4.8	4.0	3.5	7.1	6.4	5.6
147-151	3.7	2.0	1.6	1.5	1.6	2.3	2.4	3.9	4.0	3.8	4.7	6.2	9.6	6.9
152-156	1.6	.2	.7	.3	.9	.5	.7	1.4	1.8	2.1	2.0	2.4	3.8	4.3
157-161	2.6	—	.7	.5	1.1	.3	1.3	1.4	1.8	1.9	3.0	4.9	6.4	10.8
162-166	.7	—	.3	—	.5	.2	—	.2	.3	.8	.8	2.2	1.8	2.1
167-171	1.1	.2	.1	.2	.6	.7	.1	.2	.7	1.3	1.4	1.9	2.8	4.4
172-176	.3	—	—	—	.2	.3	—	—	.2	.2	.4	.9	.6	1.6
177-181	.6	—	.6	—	—	.2	.1	—		.2	1.0	.9	1.8	1.3
182-186	.3	—	—	—	.2	.2	.3		.2	.2	.6	.6	.4	.8
187-191	.1	—	—	—	—	.2	—	.3	—	—	—	.2	.8	.3
192-196	.1	—	—	—	—	—	—		.2	.4	—	.2	.6	.3
197-201	.1	—	.1	—	—	—	—	—	—	—	—	.2	.2	.8
202-206	.0	—	—	—	—	—	—	—	—	—	—	—	—	.2
207-211	.1	—	—	—	—	—			—			.4	—	.7
212-216	.0	—	—	—	—	—	—	—		—			—	.2
217-221	.1	—	—	—	.2	—	—				.2	.2	.2	—
222-226				—	—	—	—					—	—	—
227 and over	.0	—	—	—	.2	—		—		—				

Sy t l c Blood Pre ure m mer y	Tot l 7977 190 0	16 100 0	17 100 0	18 100 0	19 100 0	0–4 100 0	5 9 100 0	30–34 100 0	35 39 100 0	40–44 100 0	45–49 100 0	50 55 100 0	55 59 100 0	60–64 100 0
76 nd u d	0	—	—	1	—	—	—	—	—	—	—	—	—	—
7–81	1	—	—	—	1	1	—	—	—	2	2	—	—	—
8 86	1	—	—	—	3	3	2	—	—	—	—	—	—	—
87 91	9	5	1 5	9	2 2	1 3	8	9	5	2		4	2	—
92 96	1 4	3 2	1 9	1 2	3 3	2 5	1 2	1 4	3	2	1 1	—	2	—
9 101	5 8	6 5	7 6	7 4	8 0	8 3	8 1	5 5	3 4	4 7	3 6	1 7	2 4	5
102 106	5 9	8 3	7 3	/ 7	5 6	9 9	6 9	7 2	4 2	4 4	3 1	1 1	7	2 6
107 111	12 6	17 6	15 4	14 1	17 8	16 3	17 0	14 5	12 2	8 4	6 8	5 3	4 5	3 1
112 116	10 7	14 8	14 5	16 2	16 9	1	13 1	10 9	6 8	4 7	6 2	2 9	4 9	2 1
117 121	20 5	25 0	27 8	23 9	21 2	22 8	25 9	21 4	20 3	17 4	16 2	14 5	9 7	7 9
122 126	10 8	9 7	11 7	11 4	12 3	10 7	10 8	12 3	12 7	14 3	6 0	8 4	7 5	6 3
127 131	10 5	6 9	5 7	8 4	6 4	8 7	8 4	10 8	1 2	16 0	14 8	13 5	12 5	12 0
13 136	4 1	2 3	3 0	2 9	1 7	2	3 7	5 1	6 1	6 2	5 3	5 3	7 0	4 7
137 141	6 2	2 8	1 8	2 1	2 2	1 8	2 4	4 7	8 2	9 6	13 5	15 1	15 0	13 1
142 146	1	1 4	3	5	6	8	2	1 1	2 3	3 0	4 0	3 8	3 8	5 8
147 151	2	—	3	6	8	1 4	8	1 7	2 4	3 4	6 0	6 5	9 2	11 0
152 156	9	—	1	1	1	1	3	2	1 1	7	2 7	2 9	3 3	2 6
157 161	1 7	—	3	—	1	—	—	9	1 4	2 4	3 6	5 2	7 1	7 9
162 166	6	—	3	1	—	—	—	3	—	1 0	5	1 9	1 9	4 7
167 171	10 0	5	—	—	2	—	3	8	3	1 3	1 8	4 4	3 3	3 1
1 176	3	—	1	1	—	1	—	—	—	3	7	1 3	1 0	2 1
177 181	7	—	—	—	—	—	2	2	2	8	1 5	3 1	2 3	3 7
182 186	2	—	—	—	—	—	—	—	2	2	5	6	5	2 1
187 191	3	5	—	—	1	—	—	—	2	2	5	1 1	7	2 6
192 196	1	—	1	—	—	—	—	2	—	—	2		2	5
197 201	2	—	—	—	—	—	—	—	—	2	2	2	1 6	1 6
202 206	0	—	—	—	—	—	—	—	—	—	—	2	—	—
207 211	0	—	—	—	—	—	—	—	—	—	—	—	2	—
212 216	0	—	—	—	—		—	—	—	—	—	—	2	—
217 221	0	—	—	—	—	—	—	-	—		—	—	—	—
222 226	0	—	—	—	—	—	—	—	—	—	—	—	2	—
27 a d over	0	—	—	—	—	—	—	—	—	—	—	4	—	—

TABLE 3 —DISTRIBUTION OF DIASTOLIC BLOOD PRESSURE READINGS BY SEX AND AGE

Data D r ed f o 1 Medi al Exam nations of Employe s and Appli ants f 11 Large Industrial Plants and A my Ai Field (Civilians only) Sampl of Enti e Exper ence

Males

Dia tol c Blood Press re m m rcury	Tol l 7557 100 0	16 100 0	17 100 0	18 100 0	19 100 0	0- 4 100 0	5 9 100 0	30 34 100 0	35 39 100 0	40 44 100 0	45 49 100 0	50 54 100 0	55 59 100 0	60-64 100 0
						P r Lent of Total								
7 11	—	—	—	—	—	—	—	—	—	—	—	—	—	—
12 16	—	—	—	—	—	—	—	—	—	—	—	—	—	—
17-21	0	—	—	—	—	—	—	—	2	—	2	2	—	—
22 26	0	—	1	—	2	—	—	—	—	—	—	—	—	—
27 31	0	2	—	2	—	2	—	—	—	—	—	—	—	—
32 36	0	2	—	—	—	—	—	—	—	—			—	—
37-41	1	—	1	—	6	2	—	2	2	2	—	—	—	—
42-46	1	9	1	—	2	2	1	2	—	—	—	—	—	—
47-51	5	9	1 2	2 3	9	5	4	—	—	—	—	—	2	3
52 56	6	2 7	1 3	1 0	1 1	7	3	2	2	2	2	—	2	2
57 61	5 0	9 0	8 4	8 7	9 5	7 6	3 8	4 7	3 7	1 9	1 4	2 1	8	2 1
62 66	4 3	10 6	5 1	6 9	6 3	7 7	3 5	4 2	2 5	1 7	3 2	1 9	1 8	1 0
67 71	16 9	20 4	25 3	22 1	21 6	17 9	17 5	16 0	14 1	14 6	12 6	10 5	13 4	11 0
72 76	12 6	17 9	14 7	14 4	13 6	13 0	14 7	13 4	9 5	11 2	10 3	9 2	8 8	12 1
77 81	26 0	20 1	23 8	24 2	25 0	27 1	12 5	28 7	30 3	24 2	27 3	27 3	26 6	22 0
82 86	12 9	8 4	13 3	10 3	12 0	12 3	11 9	14 5	15 6	18 9	15 2	12 5	12 6	10 0
87 91	11 6	5 9	5 3	7 5	5 8	9 2	9 7	11 8	13 3	17 2	14 6	17 4	18 8	17 7
92 96	3 4	1 1	4	8	1 4	1 5	2 8	3 1	5 2	4 2	5 9	7 7	5 4	5 9
97 101	3 8	1 1	4	1 1	1 4	1 6	2 1	2 1	3 5	4 4	5 5	7 7	9 0	11 3
102 106	8	2	4	5	3	2	3	2	8	4	1 4	1 1	2 2	2 3
107-111	7	2	—	—	2	2	3	3	3	8	1 0	1 3	2 4	2 3
112 116	1	—	—	—	—	—	—	—	—	—	8	4	4	3
117-121	2	—	—	—	—	—	—	3	5	2	4	7	2	8
122 126	0	—	—	—	—	—	—	—	—	—	—	—	—	2
127 131	0	—	—	—	—	—	—	—	—	—	—	—	2	2
132 136	0	—	—	—	—	—	—	—	2	—	—	—	—	2
137 141	0	—	—	—	—	—	—	—		—	—	—	2	2
142 146	—	—	—	—	—	—	—	—	—	—	—		—	—
147 151	0	—	—	—	—	—	—	—		—	—	2	—	—

Females D tol c Bl od P e m	T t l 9 7 100 0	16 100)	17 109 0	18 100 0	19 100 0	0– 4 100 0	5 9 100 0	30–34 100 0	35 39 100 0	40 44 100 0	45 49 100 0	50 54 100 0	55 59 100 0	60 64 100 0
							I er C t of Tot l							
7 11	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1 16		—	—	—	—	—	—	—	—	—	—	—	—	—
17 21	0	—		—	—	—	—	2	—	2	—	—	—	—
22 26	0	—	—	—	1	—	—	—	—	—	—	—	—	—
27 31	0	—	—	1	—	—	—	—	2	—	—	—	—	—
32 36	0	—	—	1	—	—	—	—	—	—	—	—	2	—
37 41	1	—	—	—	—	3	—	5	3	—	—	—	—	—
42 46	1	9	—	—	2	3	—	2	3	—	—	—	—	—
47 51	8	5	2 1	8	1 2	1 4	9	8	2	—	2	4	3	—
52 56	1 3	3 2	1 9	1 2	3 1	2 2	1 1	5	3	8	7	2	—	5
57 61	8 5	7 4	10 9	14 2	13 4	13 9	9 4	8 3	4	3 5	3 1	2 [illegible]	1 7	2 1
6 66	6 4	9 3	8 4	7 9	8 4	10 1	6 8	8 1	3 4	3 0	4 0	2 5	2 6	3 [illegible]
67 71	23 1	31 9	27 7	29 0	31 8	7 4	29 7	22 3	20 0	15 0	13 1	13 2	12 0	8 9
72 76	13 3	19 4	17 1	15 8	12 5	12 9	14 0	15 4	13 8	15 2	10 [illegible]	9 0	5 9	9 4
77 81	23 0	13 9	19 3	22 9	19 9	18 6	22 5	24 8	25 1	27 5	27 6	22 9	25 9	23 6
82 86	8 7	6 5	8 5	4 5	6 2	6 6	8 5	7 2	15 1	15 0	10 0	8 4	11 1	9 0
87 91	8 4	3 7	2 5		2 9	4 7	5 6	7 6	12 6	10 8	15 9	0 9	17 6	16 8
92 96	2 0	9	7	8	1	1 0	2	1 9	1 0	2 7	3 5	5 7	6 8	6 3
97 101	2 7	2 3	6	4	1	4	[illegible]	1 4	4	3 9	6 8	8 4	7 8	11 0
102 106	4	—	—	1	—	—	2	—	2	8	[illegible]	1 1	1 7	1 0
107 111	9	—	—	—	1	1	3	5	8	8	2 4	3 6	1 7	4 7
11 116	1		—	—	—	—	—	3		2	—	—	2	1 0
117 121	2	—	—	—	—	—	—	—	—	3	4	6	1 0	1 0
122 126	1	—	f	—	—	—	—	—	—	—	5	2	—	5
127 131	0	—	—	—	—	—	—	—	—	2	—	—	2	—
132 136	0	—	—	—	—	—	—	2	—	—	—	—	2	—
137 141	—	—	—	—	—	—	—	—	—	—	—	—	—	—
142 146	—	—	—	—	—	—	—	—	—	—	—	—	—	—
147 151	0	—	—	—	—	—	—	—	—	—	—	2	—	—

T le 4—S t c nd D t c B o d ... A co ... to H ... ht and We ght Group

M ... d d ... d eff ... t f v ... t ... f ... t le nd d ... t ... r ... d ... gs d eff ... t of ... 1 t
... 1 10 ... g ... p

D t d n ed f m m d ... l ... m ... t ... f m(l ...) ... 1 pr ... t ... f ... g ... d ... t ... d A m ... f ...

S ... W ght G ... p	SYSTOLIC: Sh t: M	Sh t: St d D	Sh t: C ff f V rat	Med m: Mea	Med m: St d Dev	Med m: C ff f V	Tall: M	Tall: St d Dev	Tall: C ff f V	C ffic ent f C ... : Sh t	C ffic ent f C ... : M d m	C ffic ent f C ... : T ll
M l												
0 J												
10% m ... d ... ght	1 0 8	13 79	10 09	1	13 10	10 C9	1 3	10 83	8 3	C 37	3 3	43
A ... g ... gl t	1 1 5	1 43	10 3	124 4	14 08	11 3	124 4	1 33	9 6	549	3 0	415
10 ... 47 ... gl t	1 3 2	3 8	7 04	1 5	11 09	9 8	120 0	13 36	10 10	541	401	183
w gl t				1 5 4	11 83	9 43					638	
30 3												
10% m ... d ... ght	12 2	16 11	12 93	122 7	12 C7	10 33	125 1	14 59	11 6C	518	5C9	490
A ... g ... gl t	124 1	14 8C	11 97	1 3	12 C7	10 06	1 9 3	13 54	10 55	C 1	5 3	354
10 4 ... gl t	1 7	11 10	8 3	1 8	13 54	10 4	133	15 0	11 8	037	541	387
5% n ... ght				134 6	13 09	10 39					701	
40 4												
10% m ... d w ght	1 9 3	2 C3	17 64	1 6 8	15 12	11 9	129 9	14 02	10 89	34	6 3	4C2
A ... t	128 5	1 6C	1 13	130 6	15 0C	11 3	1 8 4	14 00	10 11	3C	607	7 1
10 4% ... w gl t	13 0	23 15	17 54	130 9	10 87	1 83	130 0	13 42	10 32	C 38	C 0	439
5% m ... w gl t				133 J	10 4	1 13					719	
0 9												
10% m ... d ... ght	13C 3	19 5	14 12	134 2	17 C7	13 17	131 2	10 48	1 6	C 3	C36	614
A ... gl t	135 1	18 42	13 63	13C 3	13 3	14 11	137 4	13 84	14 45	C	C46	6 9
10 4 ... gl t	139 5	21 3	1 43	139 7	9 8C	14 93				10	8 1	
5% m ... w l t				140 8	8	15 8					813	
l m les												
0)												
10% m ... d ... gl t	113 6	10 6	3 30	114 0	11 3	9 13	115	13 8	11 3			
A w ght	113 6	11 0C	3 4	116	10 C1	9 13	114 J	11	3 9	07	1	3 6
10 4% ... gl t				116 8	11 11	9 1	1 0 4	1 46	7 86	83	57C	619
ght	1 3	13 4	10 83	1 4 5	13 39	10 70	1 0 3	18 9	15 3		530	558
30 39										81	C34	C8
10% ... d w gl t	118 0	14 4	1 2	117 9	11 1	10 14	11	14 89	1 46			
A ... g ... gl t	1	13 91	11 36	113 8	12 10	10 10	1 4 0	15 8	1 81	C 8 6	604	678
10 4 ... w gl t				1 5 8	1 14	1 47	1 4 8	14 80	11 86		C30	C44
gl t	1 4 8	11 83	4 48	1 7 7	14 C1	11 44	130 1	11 7	J 0		5C4	815
40 43										6C	C83	747
10% mor ... d ... gl t	120	1 C1	11 00	124 0	1 34	1 85	1 0	13	19 83			
A rage ... gl t	130 0	0 11	1C 08	1 8 6	16 53	12 85	1 8 4	17 C7	13 6	J	C73	834
10 4% ... gl t	1 8 6	16 88	13 33	132 3	18 C0	14 06	136 4	18 50	13 8	7 8	715	C50
m ... gl t	137 7	16 44	11 34	135 J	0 0	14 7	13	21 8	1 C5	16	714	471
50 9										880	700	711
10% m ... t ... t	137 3	3 06	18 83	13 9	19 40	14 C0	134 2	16 6	12 64			
Average ... gl t	13 3	2 38	18 0	135 8	13 34	14 3	137 8	3 17	18 81	686	710	758
10 4 ... w ... t	144 3	23 27	18 13	140 0	22 43	16 02	1 4	1 53	14 20	745	21	7 6
m ... w gl t	133 4	16 4	12 01	148 3	22 53	15 13				388	719	694
										C83	671	

DIASTOLIC

S ly ff ght C	Short Mea	Short St d Dev	Short C ff f V n	Med m M	Med m St d Dev	Med m C ff t V t	T ll Mea	T ll St d Dev	T ll C ff f V t	C ff t f Cor l t Sh t	C ff t f Cor l t Med m	C ff t f Cor l t Tall
M les												
(0 1)												
10 (ght	4 3	9 48	1 6	5 6	9 17	1 13	75 6	7 4	9 07	(97	3 3	43
A gl)	6 6	9 (	1 6	6 0	3 44	1 4	2	9 85	12 76	49	370	415
10 4 gl l	9 4	))	11 8	73 7	8 39	10 51	78 0	0 67	1 40	541	401	(83
gl)				93 0	8 7	10 33					638	
30-39												
10 m (ght	7	11 1	14 83	76 8	9 13	11 89	77 1	0 91	1 85	509	69	490
A gl)	1 7	10 11	13 7	8 9	0 36	11 86	80 1	8 01	10 00	6 1	9	354
10 4 t t	73 3	11 43	14 31	8 3	10 37	1 60	8 3	11 83	14 45	63	41	387
g t				80 0	10 8	12 3					701	
40 49												
10 m l gf	81)	11 17	14 6	9	0 71	11 38	80 1	0 04	11 99	74	(3	462
A g gl t	81 4	11	14 41	81 4	0 93	1 0	81 6	10 11	1 39	16	607	79
10 4 gl t	84 3	10 60	1 57	84 3	10 30	1 7	83 0	6 17	8 40	(16	610	433
m re ght				85 3	10 4	12 74					713	
50 59												
10 m n l t t	81 8	11	14 09	8 5	10)	13	80 6	9 79	11 53	(73	(36	614
A g gl t	83 3	9 80	11 6	83 4	11 47	13 7	85 0	10 18	12 0	6 2	040	6 9
1) 4 w gl t	83 6	14 (1	17 48	80 4	11 41	13 30				10	8_1	
5 m ght				10 4	14 36	15 93	*				913	
J l												
0)												
((mo l ght	( )	8 14	12 43	71 4	) 24	1 14	0 9	9 (1	13 55	507	21	3 6
A gl t	)	8 15	1 7	7 5	8 87	12 3	74 1	0 5	12 81	583	5 6	01)
11 4 ht					0 17	13 75	76 9	7 14	10 33		536	558
m gt	(7	9 39	) 4	77	10 71	13 09	73 7	11 9	10 13	81	(34	68
30 3)												
(n) gl t	3 (	12 61	17 13	4)	0 81	13 35	4 0	1 8	1 18	5 8	604	(8
A gl t	6	17 (1)	13 4	74 7	3 34	12 0	77 6	) 4	11 11	(8	630	644
10 4 ght				78 0	9 40	12 17	80 4	1)	16 07		64	815
m gl t	8 7	9 1	1 34	91 8	9 90	1 11	85 7	10 8	1 00	(02	(83	47
40 49												
((n) gl	75 1	10 81	14 31	77 8	9 38	1 06	75 6	10 0	13 49	79	873	834
A gl t	80 1	1 1	15 4	73 7	10 36	13 00	80 4	0 5	11 50	7 8	715	600
10 4 ght	83 8	11 93	14 27	93 5	1 51	14 09	93 3	9 83	11 82	7 16	714	4 1
m gl t	97 3	8 88	10 17	8 2	11 98	14 06	83 4	11 84	13 74	880	00	711
50)												
10 l gl t	80 6	11 93	14 90	90 7	10 43	1 92	83 3	9 9	11 65	(8(	710	7 9
A ght	8 6	1 3	14 97	8 1	10 31	12 65	83 9	11 10	14)	45	7 1	706
10 4 w ght	8 5	13)	16 13	93 1	14 10	10 38	87 0	15)	17 03	398	71)	(84
5 m ght	83 0	10 09	11 34	87 8	13 39	15 4				(93	6 1	

N t g 6 t l tl 0 ses

TABLE 5 — DISTRIBUTION OF SYSTOLIC BLOOD PRESSURE READINGS
ALL AGES COMBINED

Tens	Units 0	1		3	4	5	6	7	8	9	Total
50	—	—	—	—	—	—	1	—	—	—	1
60	—	—	—	—	—	—	—	—	—	—	—
0	—	—	—	—	—	—	1	—	—	—	1
80	4	—	1	—	5	—	1	—	8	—	19
90	93	—	36	—	40	5	65	—	144	4	38
100	500	—	157	1	297	79	222	3	359	5	1623
110	1351	3	457	6	340	188	491	6	920	5	3 67
120	2128	3	675	5	569	1 8	391	5	509	4	445
130	1350	—	300	-	270	102	210	2	313	1	2555
140	85	4	162	5	97	56	99	1	132	—	1413
150	380	1	43	2	58	34	61	—	2	—	652
160	26	—	23	1	44	19	16	1	3	—	408
170	130	—	13	—	16	14	11	—	21	—	205
180	81	—	3	—	13	12	9	—	5	—	1 3
190	31		5	—	4	3	5	—	5	—	53
200	23	—	1	—	1	—	1	—	—	—	26
210	8	—		—	2	—	—	—	—	—	10
220	5	—	—	—	—	1	—	—	3	—	9
230	—	—	—	—	—	—	—	—	—	—	—
240	1	—	—	—	—	—	—	—	—	—	1
250	1	—	—	—	—	—	—	—	—	—	1
	7210	11	18 6	27	1756	691	15 4	18	2528	20	15711

TABLE 6 — DISTRIBUTION OF DIASTOLIC BLOOD PRESSURE READINGS
ALL AGES COMBINED

Tens	Units 0	1		3	4	5	6	7	8	9	Total
0	—	—	—	—	—	—	—	—	—	—	—
10	2	—	—	—	—	—	—	—	—	—	2
20	5	—	1	—	2	—	1	—	1	—	10
30	4	1	1	—	—	1	1	—	1	1	10
40	14	—	6	—	1	5	6	—	15	—	4
50	89	—	19	—	42	13	75	—	175	—	413
60	881	3	180	2	324	92	239	1	689	7	2418
70	2443	3	530	7	555	190	753	5	952	10	5448
80	2963	2	480	2	645	114	442	4	329	7	488
90	1235	—	138	—	107	43	136	1	160	—	1820
100	354	—	28	1	25	27	17	—	20	—	472
110	106	—	6	—	4	3	5	—	7	—	131
120	29	—	2	—	3	1	2	—	—	—	3
130	5	—	2	—	—	1	1	—	—	—	9
140	4	—	—	—	—	—	—	—	—	—	4
150	2	—	—	—	—	—	—	—	—	—	2
160	—	—	—	—	—	—	—	—	—	—	—
	8036	9	1393	12	1708	490	1678	11	2349	25	15711

Chapter VI

INTERPRETATION AND CLINICAL APPLICATION OF NEW BLOOD PRESSURE LIMITS

MUCH useful clinical information has been acquired as a result of the general adoption of sphygmomanometry about fifty years ago The sphygmomanometer has been of particular value as an aid in the diagnosis of hypertension but the use of the sphygmomanometer has not been wholly beneficial When new clinical and laboratory procedures are introduced improper interpretation of the results obtained through their use often causes much harm and sphygmomanometry has been no exception After approximately fifty years of the application of the sphygmomanometer to the care of the sick an assay of its value would not yield a wholly favorable balance sheet Unhappily it is probable that as many patients have been harmed as have been helped owing to its injudicious use by both physicians and laymen (Perera and Atchley[117]) Houston[76] discussing the same problem concludes that the measurement of blood pressure often serves to focus anxiety on certain figures which the patient interprets as ominous and which the doctor can do little about save to allay the anxiety which he has occasioned he later says that the goal to be sought is always intelligent utilization of information not binding oneself to the facts of a situation

Since there has been a great increase in the older age groups of the population during the past several decades and since hypertensive and other cardiovascular diseases are the leading causes of death in the United States * widespread publicity has been given to the importance of blood pressure readings and public attention has been focused on the subject Physicians as well as the laity have thus become very sensitive to variations of the blood pressure levels from the so called normal limits The number of patients who appear in offices of internists or cardiologists simply because they have been told that they have high blood pressure is now so large that the use of the expression blood pressure phobia is justified In the great majority of instances this concern over the blood pressure level is unnecessary and undesirable

* The American Heart Association[7] recently published provisional official figures on the mortality rate during 1950 in the United States More than 745 000 individuals died from diseases of the heart and blood vessels including hypertension The other 5 important causes of death (cancer accidents pneumonia tuberculosis and nephritis) took a toll of only 407 000 individuals Thus heart and vascular diseases produce almost twice as many deaths as do all the other five major causes of death combined

The proper clinical interpretation of individual blood pressure readings has been and still is a most difficult problem since the limits of the normal and abnormal have hitherto not been clearly defined. Many physicians have accepted somewhat arbitrarily fixed limits of the normal blood pressure without giving due consideration to the various factors which cause these limits to vary, e.g. age, sex and vascular conditions. Age and sex particularly exert an important influence on the blood pressure and should be considered in each case. Since the present commonly accepted "normal" limits are entirely too low, many people (especially in the older age groups) have been classified as hypertensives.

The new normal blood pressure limits now proposed are higher than those hitherto accepted and do make allowance for the effects of age and sex on the blood pressure. With these new limits many patients who have been considered hypertensive will now be considered normal; they will thus be relieved of the anxiety and emotional strain often associated with the fear of a high blood pressure, as well as of the seeming need for medication to reduce their pressure.

In evaluating blood pressure readings the proposed new limits must be reasonably applied. Too much attention is often paid to the height of the blood pressure and not enough to the clinical picture as a whole. In clinical medicine the blood pressure level is not as important as is the absence or presence of underlying vascular disease. Increased blood pressure in itself is not a disease. It is a sign of some underlying disorder. Many studies[270b, 278–81] have shown that there is little or no correlation between the height of the blood pressure and the symptoms, the rate of progression, and the development of complications of the underlying disease. The most important factor in determining the prognosis and future course of patients with hypertension is the presence of vascular disease as manifested by cardiac enlargement, albuminuria, hypertensive encephalopathy, eyeground changes and electrocardiographic alteration. Bechgaard,[66] in a four- to eleven-year follow-up study of 1002 hypertensive patients, found that elevation of the systolic pressure to 200–220 mm mercury and of the diastolic to 120–130 mm mercury had not too significant an effect on the mortality rate; when the elevated blood pressure was combined with myocardiac degeneration, however, the prognosis became very bad. Stieglitz,[78] Paullin[279] and Perera[63] have also shown that the degree of the arterial tension alone is wholly inadequate as a criterion of the prognosis in any individual case. Griep, Barry, Hall and Hoobler,[80] in a recent follow-up study of 117 hypertensives, again emphasized the unreliability of the height of the blood pressure or of a change in its level as a prognostic sign in hypertension, and stressed the importance of determining the degree and the progression of the vascular damage in the heart, brain, kidneys and retina.

The blood pressure reading must therefore be correlated with the clinical status of the patient as a whole and should not in itself serve as

the basis for a diagnosis or prognosis in any given case Page [5] criticizes the physician who makes a diagnosis of hypertension on the basis of the blood pressure alone and who does not search for the other signs associated with hypertension He stresses the fact that the isolated finding of an elevated blood pressure is not sufficient for a positive diagnosis This consideration is of utmost importance when the borderline group of cases is considered A careful history should be taken and a physical examination done in every case in this group Special attention should be paid to the size of the heart to electrocardiographic changes to renal function studies to the retinal examination and to the functional tests of the heart (e g 2 step test) Thus a man or woman of fifty two with a systolic pressure of 175 mm mercury or a disatolic pressure of 104 mm mercury should be thoroughly examined before the significance of the blood pressure level is evaluated If the entire examination is negative and fails to reveal evidence of vascular disease of the heart the kidneys or the fundal arteries the blood pressure may be considered normal for this particular individual However the same level of arterial pressure or even a lower one would be considered abnormal in another individual who showed evidence of some vascular damage such as increase in the size of the heart electrocardiographic changes suggestive of left ventricular hypertrophy and strain or albuminuria Just as dependence for diagnosis on any other single finding or test may be dangerous practice in clinical medicine so the evaluation of the blood pressure reading without correlation with the entire physical status of the patient is unsound

The acceptance and utilization of the newly proposed normal blood pressure limits will obviously have a wide field of application and a wide effect in the practice of clinical medicine and in clinical research The use of the new normal limits in clinical practice will be of utmost importance in relieving the anxiety which has beset many patients incorrectly classified as hypertensives Many of those who have hitherto been regarded as moderate hypertensives and who have had a gloomy outlook cast upon their futures may now be considered to have essentially normal blood pressures They will also be spared much needless medication The use of these new limits in the vast field of industrial medicine too will have a considerable effect A blood pressure reading is part of every pre-employment physical examination and is too often unduly emphasized Many men particularly those over middle age who have been rejected because of so called hypertension will again have the opportunity to be gainfully employed Since the manpower situation is now critical this effect assumes even greater importance As voluntary health and accident insurance spreads and as retirement for illness becomes more common the range of normal blood pressure will have increased application In cases in which workmen s compensation is a consideration the blood pressure may be of importance in determining the state

of health of the claimant and in resolving the relationship between the blood pressure and occupation effort or trauma In the military service during the last war blood pressure readings were taken routinely and standards were adopted for accepting and rejecting applicants as well as for appraising the need for medical care and for retirement while in service Since a large Army Air Force and Navy are again being formed the evaluation of the blood pressure is again of great military importance

The proposed new blood pressure standards should also prove to be useful in clinical research Thus the relationship of hypertension to coronary occlusion angina pectoris diabetes mitral stenosis cardiac enlargement electrocardiographic changes and other disturbances should be re-evaluated using the new limits as criteria Some studies in this field have already been undertaken and merit a brief review

1 CORONARY OCCLUSION AND HYPERTENSION

In the past hypertension has been considered to be one of the most important etiologic factors in the production of coronary occlusion For example Master Dack Jaffe and Silver[288, 29] reported studies done on over 500 cases of coronary occlusion Initial attacks of coronary occlusion were found to occur more frequently in each older age group among both men and women The incidence of hypertension also was found to rise with increasing age if the constant limits 150 95 were used as criteria Thus 28 per cent of the men under thirty five years of age had hypertension while 80 per cent of those who were seventy had hypertension In women with coronary occlusion hypertension was found to be more common being present in actually 90 per cent of those over forty four years of age *Hence the conclusion had been drawn* that hypertension is an important precursor of coronary occlusion both in males and females These findings must now be re evaluated however since it has been shown that the blood pressure normally increases with age and varies with sex and that the same limits should not be used for all ages and in both sexes in determining the presence of hypertension in cases of coronary occlusion The relationship of hypertension to coronary occlusion has recently been re investigated using the new limits of normal blood pressure that have been proposed Five hundred and fifty four consecutive patients with coronary occlusion (454 men and 100 women) under the age of sixty five were studied The cases were unselected though those over sixty four were not included in the study because the new blood pressure limits extend only to that age Among the 454 men (Table XXII) the highest incidence of coronary occlusion was found in the fifty to fifty four year age group (121 cases) and the second highest in the fifty five to fifty nine year age group (105 cases) Among the 100 women the highest incidence of occlusion occurred in the sixty to sixty four year age group (32 cases) and the second highest

in the fifty five to fifty nine year age group (28 cases) Seventy eight per cent of the women were over fifty years of age as against 63 per cent of the men Women therefore tend to be older than men when the first attack of coronary occlusion occurs In this series of cases the average age at which men sustained their first attack was forty eight while the average age of the women was fifty two In another series (Wright[91] and others[287]) the women were on the average 6 years older than the men at the time of the first attack of coronary occlusion

TABLE XXII —INCIDENCE OF HYPERTENSION IN CORONARY OCCLUSION

Age Groups	Male				Female			
	Total Cases		Hypertension		Total Cases		Hypertension	
	No	%	No	%	No	%	No	%
All Ages	454	100 0	124	27 0	100	100	71	1 0
25 29	0	—	0	—	0	—	—	—
30–34	3	0 7	1		0	—	—	—
35 39	18	4 0	3	16	4	4 0	3	5 0
40 44	66	14 5	1	5 8	9	9 0	4	44 4
45 49	80	17 6	22	2 5	9	9 0	7	77 6
0 54	121	26 7	35	28 9	18	18 0	14	7 8
55 59	105	23 2	27	25 6	28	28 0	18	64 4
60–64	61	13 4	19	31 2	32	32 0	25	78 2

Less than 3 per cent not calculated

Three possible explanations can be given for the later occurrence of coronary occlusion in women than in men

1 Since women after forty normally have a higher blood pressure than do men they may have a better coronary circulation and flow than men of the same age

2 Women tolerate hypertension much better than do men and its course in women is more benign A longer period of time may be required therefore for women to develop coronary sclerosis as a result of the hypertension

3 Men have a much greater tendency to develop coronary sclerosis than do women This may be due to endocrine factors or as suggested by Dock[29] to the fact that males are born with a thicker coronary intima than females

Since the arterial tension almost invariably falls after an occlusion the blood pressure which had been present before the occlusion occurred was definitely ascertained in 454 of the cases studied The readings were obtained either from the referring physician or from the patient if he

actually knew what they were. Frequently the investigators themselves had measured the pressure before the occlusion developed. In 99 cases no previous readings were available, though the patient may have known whether his blood pressure had ever been high or low. Thus, if the patient had had no difficulty in passing an insurance examination in the recent past, it was assumed that his blood pressure had been normal. Furthermore, clinical judgment was also used in evaluating the blood pressure. If, for example, the blood pressure was 160/100 mm. mercury on the second or third day of the coronary occlusion, it had probably been higher before the attack. If the blood pressure returned to a hypertensive level a few months or a year after the acute coronary episode, the patient was probably hypertensive before the acute attack had occurred. Consideration also was given to the finding that about one third of hypertensive patients lose their hypertension permanently after an acute coronary occlusion. The borderline cases were omitted in the tables shown because there were so few of them, and because a clearer picture can be obtained by comparing cases at the two extremes—those with definitely elevated blood pressure and those with a normal reading.

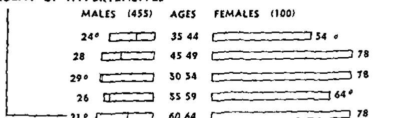


Fig. 36.—Frequency of hypertension in 455 cases of coronary occlusion (blood pressure readings taken before the onset of coronary occlusion).

Using the new definitions of "hypertension" according to age and sex, 195 (35 per cent) of the 554 patients studied were found to be hypertensive. The frequency of hypertension was higher among the women (71 per cent) than among the men (27 per cent). In each age group the frequency of hypertension among the women was more than twice that among the men (Table XXII and Figure 36). It will be noted that the frequency of hypertension varied little in the various age groups. Using the new limits, the incidence of hypertension remained fairly stationary even though the actual blood pressure rose with increasing age. Previous reports, which were based on a single definition of hypertension for all age groups, e.g., 150/90, and which did not take into account the normal increase in blood pressure with increasing years, erroneously showed that the incidence of "hypertension" in patients with coronary occlusion rose with age.

The striking finding in this study was that hypertension was present in only 27 per cent of the males To put it positively over 70 per cent of the men who suffered coronary occlusion had normal blood pressures The evident conclusion to be drawn is that there is no very close relationship between hypertension and coronary artery disease and occlusion in the males at least in those under sixty five years of age The reverse was true in the women—71 per cent of those who had a coronary occlusion did have hypertension Thus among women hypertension does appear to have an important relationship with coronary occlusion These findings were substantiated by Zeman and Schwartz[293] in a recent post mortem study of 150 unselected cases from the Home for Aged and Infirm Hebrews of New York City All of the patients had been over sixty years of age Sixty six were male and 84 female They were divided into 3 groups—those with normal blood pressure those with systolic hypertension and those with both systolic and diastolic hypertension Among the males there was no significant difference in the incidence of coronary occlusion in the 3 groups Among the females the incidence of coronary occlusion in both groups with hypertension was the same None of the females with normal blood pressure suffered from coronary occlusion Zeman and Schwartz thus confirm our conclusions—that hypertension does not appear to be an important factor in producing coronary artery disease and occlusion in males but is an important factor in producing these diseases in females In coronary artery disease with angina pectoris which is the underlying condition for coronary occlusion the same trend exists[294, 29]

BLOOD PRESSURE LEVEL CORONARY OCCLUSION AND ENLARGED HEART

Using the new limits of normal blood pressure we have re-examined and re evaluated the relationship between hypertension coronary artery disease and coronary occlusion The relationship between hypertension and cardiac enlargement as well as between coronary artery disease and cardiac enlargement has not yet been clearly established Although very many investigators[96, 311] have maintained that coronary artery disease alone does not lead to an enlargement of the heart many others[83, 309–311] have held the opposite point of view

We have attempted in this study to determine whether hypertension alone or coronary artery disease alone is related to enlargement of the heart A heart was considered to be enlarged if its total transverse diameter was definitely greater than one half of the internal thoracic diameter at the level of the diaphragm The shape and general silhouette of the heart were also considered Ungerleider and Clark tables were used, in each case as a further check on the presence or absence [of] ca[…]

diac enlargement. In each case studied the area and volume of the heart were evidently increased beyond the normal.

One hundred and twenty two of our 554 cases of coronary occlusion (454 men and 100 women) (22 per cent) had a cardiac enlargement (Table XXIII). Among these there were 78 men (17.2 per cent) and 44 women (44 per cent). The incidence of enlargement of the heart was much higher in women than in men, as was the incidence of hypertension. However, *cardiac enlargement was found to increase in frequency with advancing age* whereas hypertension did not increase with age in either sex. From this one could reason that the coronary artery disease which was *present in these cases could be a primary factor in the causation of the* cardiac enlargement. Other evidence also supported this conclusion: cardiac enlargement was found in 47 patients whose blood pressure was normal *prior to the coronary attack* (Table XXIV). *Of these* 42 were men and 5 were women. In our series of patients with coronary occlusion and with enlargement of the heart, hypertension was found in 25.8 per cent of the men, and normal blood pressure in only 13.9 per cent. In females with coronary occlusion and with enlargement of the heart hypertension was found in 52.2 per cent, and normal blood pressure in 23.8 per cent. These results coincide with the common observation that hypertension is a definite *factor in enlargement* of the heart. Nevertheless an enlarged heart can also be found with normal blood pressure. At least in men coronary artery disease alone appears to be a major factor in the enlargement of the heart. We have shown previously that in cases with coronary occlusion (554 cases) hypertension was found in 27 per cent of males and in 71 per cent of females prior to the occlusion. It seems there

TABLE XXIII.—CORONARY OCCLUSION AND ENLARGEMENT OF THE HEART

Males				*Females*			
Age Group	*Total No. of Cases*	*No. with Enlarged Heart*	*% with Enlarged Heart*	*Age Group*	*Total No. of Cases*	*No. with Enlarged Heart*	*% with Enlarged Heart*
All Age	454	78	17.2	All Ages	100	44	44.0
25–29	0	0	—		0	—	—
30–34	3	0	—		0	—	—
35–39	18	3	16.7	35–39	4	0	—
40–44	65	9	13.9	40–44	9	1	*
45–49	80	11	13.8	45–49	9	4	44.5
50–54	121	15	12.3	50–54	18	5	27.8
55–59	105	22	21.0	55–59	28	12	42.9
60–64	61	18	29.5	60–64	32	22	68.8

* Less than 3 cases, per cent not calculated

T XXIV —E LARGEM O T HEART D BLOOD PRESS RE N 5›4 C OF CO O Y OCCLU I N

	Mal							F mal						
		Hyperten io			N mal				Hyperten io			Normal		
	G d T tal	T tal H	N E H	% E H	Total N	N E H	% E H	G d T t l	T tal H	N E H	% E H	T tal N	N E H	% E H
All Ages	4›4	1 3	3	8	30[illegible]	4	13 9	100	71	3	5 [illegible]	1	5	3 8
30–34	3	1	0	—	2	0	—	—	—	—	—	—	—	—
35–39	18	3	1		14	2		4	3	0	—	1	0	—
40–44	65	17	5	29 5	47	4	8	9	4	1		5	0	—
45–49	80	[illegible]	5	[illegible] 8	54	6	11 1	9		3	4 9	0	—	—
50–54	122	3	5	14 3	81	10	12 4	18	14	5	3 8	4	0	—
55–59	105	26	7	27 0	69	12	17 4	8	18	8	44 4	7	4	7
60–64	61	19	9	47 3	3.	8	9	32	2	[illegible]0	80 0	4	1	

29 ases w th b d l blood p ess we mitt d
4 f these h d nlarged hearts
Less tha 3 ases pe ce t n t c lcul ted
H hyp t
EH l g d heart
N n rm l

8 cases w th b d l blood p ss es w re mitted 2 f these had l ged h rt
Less th 3 ase p ce t not l l t d

T L XXV —BLOOD P SSURE D ST UTI N 68 C WI H C FNL M NT
(F m m g 543 I t P t t)

	Mal					Femal				
Ag Group	T t l N mber f Cas	N mber with E l g d H t	Hyper Tens	Border l	N mal Ten io	T tal N mber f C	N mb with Enl ged Hea t	Hyper Tens	B d l	Normal Tens
U d 20	1					—				
20–34	30					[illegible]				
35–39	38	1	—	—	1	14	—	—	—	—
40–44	53		2	—	—	18	2	2	—	—
45–49	79	4		1	1	23	1	1	—	—
50–54	8.	17	13			30	6	4	1	1
55–59	63	13	8	4	1	13	4		—	2
60 64	5	10	6	1	3	1	8	3	1	4
T t l	404	4	31	8	8	139	1	1	2	7

Th ze f th heart was d t rm ed 1000 consecut v privat p t ts f th se or th Of these 543 ere on d ed tabl f th p ese t t dy Th th 4 7 p t ts w ex l d d beca th h rts we la ged as es lt f or ry or l h t f l re fro heum t ca lova l disease conge tal heart disease because th y w less th 16 ov 64 years f g because t ns ff t d t

fore that high blood pressure is a primary factor in enlargement of the heart in females and that coronary sclerosis alone appears to be capable of producing enlargement of the heart in males *

In order still further to resolve whether coronary sclerosis alone (in the absence of hypertension) may cause cardiac enlargement the size of the heart was *determined in 1000 consecutive private patients* Five hundred and forty three were considered suitable for this study (Table XXV) Sixty eight of these had an enlargement of the heart in 15 the blood pressure was normal A clinical diagnosis of coronary sclerosis was established in 14 of these 15 cases The evident conclusion to be drawn from these findings is that cardiac enlargement may occur in individuals with normal blood pressures and that the enlargement appears to be related to coronary sclerosis This opinion is held by many other observers also [313, 314]

Yater and his co workers[315] recently made a clinical and postmortem study of 950 men eighteen to eighty nine years of age who had had coronary occlusion They found a definite increase in the size of the heart with increasing age The presence of hypertension alone could not account for this marked cardiac enlargement Coronary artery disease therefore may have been an important factor in the production of the *enlarged heart in these cases*

Summary

The importance of the newly proposed limits of normal blood pressure and their application in all branches of medicine have been discussed It has been emphasized that the new limits should be applied reasonably and not too literally *The blood pressure reading must always be cor*related with the clinical picture as a whole especially with the presence or absence of underlying vascular disease as determined by the history the eyeground findings electrocardiographic changes renal function studies cardiac enlargement and functional tests of the heart The demonstration of such underlying vascular disease constitutes the most important evidence for the diagnosis of essential hypertension and is the most important factor in determining the prognosis

The necessity exists for re investigating the effects of hypertension in many clinical conditions using the new limits of blood pressure since these take into account the effects of age and sex on the blood pressure levels *The results of several such studies have been presented*

1 Relationship between coronary occlusion and hypertension Hitherto, it was commonly believed that there probably was an etiologic relationship between *hypertension and coronary occlusion* in both sexes Using the new limits of normal blood pressure however we have shown that such a

* Since very few of our patients were under forty and since none over sixty four was included our figures can be applied only to patients between forty and sixty four years of age However it should be remembered that only 7 5 per cent of the population was sixty five years of age and over

close relationship existed only in women in men no such important association of hypertension with coronary occlusion was found

2 Relationship of enlargement of the heart to coronary occlusion and hypertension Using the new limits of normal blood pressure we have found that enlargement of the heart not uncommonly occurred in men with coronary occlusion whose blood pressure was normal It was therefore concluded that the coronary artery disease alone was a factor in the production of the cardiac enlargement in men In women with coronary occlusion on the contrary cardiac enlargement rarely occurred in the presence of normal blood pressure Hypertension therefore appeared to be an important factor in the production of enlargement of the heart in women

3 Relationship between enlarged heart and coronary artery disease In a study of 68 patients with cardiac enlargement none of whom suffered from coronary occlusion heart failure valvular disease or congenital abnormalities 15 were found to have normal blood pressures In 14 of the 15 a diagnosis of coronary artery disease was established Again then coronary sclerosis alone in the absence of hypertension may cause enlargement of the heart

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NORMAL RANGE AND LIMITS OF HYPERTEN ION

SYSTOLIC

Age	No mal Range		Hypertension Lower Lim t	
	Male	Fem l	Mal	Femal
16	105 135	100–130	145	140
17	105–135	100–130	145	140
18	105–135	100–130	145	140
19	10ɔ–140	100–130	150	140
20–24	105–140	100–130	150	140
25–29	108 140	102–130	150	140
30–34	110–145	102 135	155	145
35 39	110–145	105–140	160	150
40–44	110–150	105–150	165	165
45–49	110–155	105–155	170	175
50–54	115–160	110–165	175	180
5ɔ–59	115–165	110–170	180	185
60–64	115–1 0	115–175	190	190

NORMAL RANGE AND LI IITS OF HYPERTENSION

DIASTOLIC

Ag	No mal Range		Hyperte on Lower L mit	
	Male	F male	M l	F male
16	60–86	60–85	90	90
17	60–86	60–85	90	90
18	60–86	60–85	90	90
19	60–88	60–85	95	90
20–24	62 88	60–85	95	90
25–29	65 90	60–86	96	92
30–34	68 92	60–88	98	95
35 39	68 92	65 90	100	98
40–44	70–94	65 92	100	100
45–49	70–96	65 96	104	105
50–54	70–98	70–100	106	108
55 59	70–98	70–100	108	108
60–64	70–100	70–100	110	110

NORMAL BLOOD PRE URE AND HYPERTENSION N w Defin t n Arthur M Ma ter M D Ch I Garf ld M D an l Max B Walt rs M D

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